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CONTENTS OF VOLUME XXIX.

[PROC. ROY. SOC. VICTORIA 29 (N.S.), PART I., 1916].

ART. I.—*New Genera and Species of Australian Hemiptera.*

BY DR. E. BERGROTH, C.M.Z.S., LOND.

(Communicated by Professor W. Baldwin Spencer, F.R.S.)

[Read 9th March, 1916.]

In a paper published many years ago[1] I have described a number of new Australian Hemiptera communicated to me by Mr. Charles French, of Melbourne. Of the material sent to me by Mr. French I had retained for further study a number of species, partly belonging to difficult groups, and among them I have found some forms which are undescribed and of which descriptions are given in the present paper. One new species of Myodochidae belongs to a genus hither known only as Palearctic, and of the three new genera of this family here described two are remarkable by showing a decidedly closer affinity to Palearctic than to Indo-Australian genera, but this is probably due to our imperfect knowledge of the Myodochidae of the Oriental and Australian regions, the members of this family being of small size and much neglected by collectors.

Fam. PENTATOMIDAE.

EUMECOPUS VERMICULATUS, n. sp.

Oval, ochraceous, head above with six percurrent fuscous or partly dark ferruginous stripes, beneath with four not well-marked pale fuscous stripes, pronotal cicatrical areas mottled with pale fuscous, an impressed spot between ocelli and eyes, and basal half of the postfrenal part of the scutellum black, connexivum traversed through its whole length by a piceous band, pleural evaporative area tinged with ferruginous, membrane blackish-fuscous, the outer veins paler towards apex, abdomen beneath with a broad percurrent sublateral ferruginous band which inwardly is rather diffuse and disintegrated into small spots, and with a median vitta on the sixth segment and the basal lobes of the female genital segment ferruginous, spiracles fuscous; first two antennal joints dark sanguineous, base of basal joint pale ochraceous, third joint pale reddish, its apical half (except extreme apex) black (last two joints wanting), rostrum dark testaceous, last joint piceous, legs purplish-red,

1 Proc. Roy. Soc. Victoria, vii., pp. 287-302 (1895).

femora toward the base ochraceous, but with some longitudinal rows of subconfluent purplish spots, tibiae above toward the base with an ochraceous streak, tarsi pale reddish, apex of last joint infuscated; above rather thickly punctate with fuscous or black, the points largely placed in transverse irregularly waved or tortuous dark ferruginous or brownish lines, head impunctate but with the dark stripes punctulate, a medium line to pronotum (narrowed toward base), a small callus at basal angles of scutellum, apical half of its postfrenal part, and veins and costal margin of corium impunctate, the piceous connexival vitta punctulate, pleurae rather sparingly punctured with fuscous, on posterior half of propleurae with black. Head slightly broader than long and a little shorter than pronotum in the middle, juga at apex somewhat convergent over the clypeus a little before its apex, first antennal joint about two-thirds the length of the head and passing its apex by more than the half, second joint half the length of first, third 4½ times longer than second, the articulation between the second and third joints distinct, but not admitting of free mobility, rostrum somewhat passing base of abdomen, its second joint a little shorter than third and fourth together. Pronotum with the lateral margins broadly and slightly sinuate, their apical third minutely denticulated, basal margin slightly sinuate, humeral spines short, directed outwards, their anterior margin forming a straight continuation of the pronotal lateral margins. Scutellum with the postfrenal part a little longer than broad and parallel in the middle. Hemelytra passing apex of abdomen by almost one-third the length of the membrane, corium reaching beyond middle of last connexival segment, its apical margin slightly sinuate behind the middle. Abdomen a little broader than the closed hemelytra, the apical angles of the segments right-angled, moderately prominent, venter irregularly finely striolate and finely remotely punctulate, impunctate in the middle, the median furrow rather broad but shallow, reaching apex of fifth segment, the distance between the exterior margin of the sublateral ferruginous vittae and the lateral margins of the abdomen occupying one-third of the distance between the spiracles and the abdominal margins, basal lobes of female genital segment somewhat rugose and sparingly granulate. Length (excl. membrane), ♀ 20 mm.

Queensland.

Somewhat related to *E. vittiventris*, Stål, but with very much shorter second antennal joint, anteriorly denticulated pronotal lateral margins, and different colour-markings.

EUMECOPUS ADVERSIDENS, n. sp.

Elliptical, above purplish brown, thickly punctate, seven stripes to head, two spots before middle of pronotum and its lateral margins as far as to base of humeral spines, a callus at basal angles of scutellum and more than the apical third of its postfrenal part, costal and apical margins of corium, its veins, a jaggered vitta in the exocorium and in the basal half of the mesocorium, a spot behind middle of mesocorium emitting a narrow vitta obliquely forwards to the cubital vein and two less distinct vittae backwards to the apical margin, and several mottlings to pronotum, scutellum, and mesocorium pale ochraceous and impunctate, connexivum red, its exterior margin ochraceous interrupted by black at the incisures, membrane black, the exterior veins whitish grey toward apex; beneath ochraceous, head with a faint brownish vitta along the bucculae, pleurae and venter punctate with pale reddish brown, posterior part of propleurae more darkly punctate, middle of venter and its lateral borders as far as to the pale spiracles impunctate, a spot at basal and apical angles of the segments black, basal lobes of female genital segment infuscated; rostrum testaceous, last joint piceous, legs purplish red, coxae, trochanters, base and two or three streaks of femora, and a broad more or less complete subbasal annulation to tibiae ochraceous, last two tarsal joints pale red. Head longer than broad and slightly longer than pronotum in the middle, clypeus a little longer than juga, apical tooth of bucculae directed forward and somewhat outward, and very slightly downward, largely visible from above, black at tip, rostrum reaching base of fourth ventral segment, second joint distinctly longer than third and fourth together; (antennae wanting). Pronotum with the lateral margins rather deeply arcuately sinuate, their apical third finely crenulate, humeral spines rather long, directed outwards and a little forwards and upwards. Scutellum shorter than head and pronotum together, the postfrenal part a little longer than broad and narrowing from base to apex. Hemelytra passing apex of abdomen by more than one-third the length of the membrane, apical margin of corium slightly sinuate near middle. Abdomen very slightly broader than the closed hemelytra, ventral furrow rather deep, reaching apex of fifth segment, basal lobes of female genital segment rugose. Length (excl. membrane), ♀ 17.5 mm.

West Australia.

A well-marked species coming nearest to *E. acanthopygius*, Stål, but easily distinguished by many characters.

Poecilometis ellipticus, n. sp.

Elliptical, above ochraceous, rather thickly but not regularly punctured with dark fuscous or blackish, head with the lateral margins from eyes to apex of antenniferous tubercles and four percurrent vittae black, the outer vitta on each side broad, paler on the juga, and on the vertex longitudinally divided by an ochraceous line near its inner margin immediately inside the ocellus, the inner vitta on each side narrow, juga entirely punctate, but puncturation on vertex arranged in three rows on each side, the ochraceous parts of the head, the pronotal lateral margins (narrowly), a callus at the basal angles of the scutellum, somewhat less than the apical half of its postfrenal part, and the outer margin of the connexivum impunctate, membrane fuscous-black with whitish veins; beneath luteous, a sublateral vitta to anterior half of propleurae, two round spots at base of front acetabula, one round spot at base of middle acetabula, spiracles, and a ring surrounding them black, head finely and sparingly punctured with brown, pleurae punctate with fuscous, blackly and more coarsely so on the metapleural evaporative area, venter coarsely but very remotely punctate with black, the punctures becoming fuscous in the centre of the disk and toward the lateral margins; rostrum and legs testaceous, last joint of the former piceous, femora and tibiae spotted with fuscous, last tarsal joint fuscous. Head as broad as long and as long as pronotum in the middle, rostrum reaching middle of second ventral segment, its second joint subequal in length to the last two joints combined; (antennae wanting). Pronotum with the lateral margins obtusangularly sinuate before middle, their apical third bluntly and obscurely crenulated, the humeral angles a little prominent, almost right-angled. Scutellum as long as head and pronotum together, the postfrenal part almost one-half longer than broad, narrowing from its base, rather narrowly rounded at apex. Hemelytra passing apex of abdomen by a little less than half the length of the membrane, apical margin of corium straight. Abdomen behind the middle slightly broader than the closed hemelytra, the apical angles of the segments a little prominent, right-angled, ventral furrow reaching apex of fifth segment, broad and shallow, almost obliterated in the fifth segment, sixth male ventral segment in the middle somewhat shorter than the two preceding segments together, male genital segment very deeply sinuated, the bottom of the sinuosity arcuate, filled up with a pale membrane. Length (excl. membrane), ♂ 14 mm.

Queensland.

Apparently allied to the insufficiently described *P. uniformis* Schout., but without the conspicuous black impunctate area of the corium, and remarkable by the coarse puncturation of the evaporative areas and venter.

Poecilometis gibbiceps, n. sp.

Rather broadly oval, luteous, above rather thickly but not uniformly punctured with dark fuscous or blackish, head mostly not or very sparingly punctate, but with four densely punctulate dark fuscous stripes, the outer one on each side percurrent, the two inner stripes only extended through the vertex or much less distinctly indicated before it, six more or less distinct longitudinal stripes to pronotum and two oblong spots to mesocorium, all composed of more thickly set dark punctures, the outermost pronotal stripe placed close to the lateral margin, the next on each side oblique, subparallel with the sublateral stripe, the two median stripes forming a straight continuation of the outer stripes of the head, the anterior mesocorial spot placed just before the middle at the cubital vein, the posterior spot a little behind the middle at the radial vein, two apical spots to pronotum extended to the posterior margin of the cicatrical areas, and a more or less distinct vitta to anterior half of mesocorium sparingly punctate, lateral margins of pronotum (narrowly), a pronotal median vitta (very narrow or obliterated in the posterior half), a callus at basal angles of scutellum, an almost percurrent median vitta to it (sometimes longitudinally punctate in the middle) and its apex (broadly), the veins of the corium, its apical and costal margins (the latter at least from base to middle), and exterior margin of connexivum impunctate, membrane blackish with whitish veins, head beneath extremely finely almost concolorously punctulate, only the bucculae and a small area adjacent to their posterior part punctured with fuscous, pectus with a fuscous sublateral streak in the anterior half of the propleurae and with an irregular sublateral spot to mesopleurae, an oblong exterior spot to the evaporative area, and a triangular spot at interior end of this area plumbeous, all pleurae (including acetabula) more or less sparsely punctate with fuscous, a subquadrate spot adjoining the base of the four anterior acetabula and the space between the exterior margin of the irregularly rugose but impunctate evaporative areas and the lateral margin of the metapleurae impunctate, abdomen beneath with the extreme

apical angles of the segments infuscated and with a small subimpressed comma-shaped fuscous spot immediately before and slightly on the inside of the spiracles which are also often narrowly encircled by fuscous, the ventral surface finely and sparsely punctate with brown, the punctures darker and more aggregated inside the level of the spiracles where they form a longitudinal band largely interrupted in the basal half of the segments within the spiracles by a transverse subtriangular exteriorly truncate spot in which the very fine punctures are colourless, as they also are in the median part of the disk and in a broad percurrent sublateral vitta inwardly reaching the spiracles, the ventral puncturation sometimes almost entirely concolorous, the only remains of the darkly punctate intraspiracular vitta being a few fuscous points forming a curved vitta between the basal margin of the segments and the interior end of the transverse impression beginning behind the spiracles, and a small transverse cluster of fuscous points of the apical margin of the segments; antennae (at least the three first joints), rostrum (except the piceous apical joint), and legs dark testaceous, femora and tibiae finely dotted with brown. Head a little broader than long, and about one-fourth shorter than pronotum in the middle, clypeus a little longer than juga, narrowing from base to near apex, its apical part deflected, juga with their apices approaching each other over the clypeus behind its apex, the apical part of their inner margin almost perpendicularly deflected (a character well seen from the front), vertex gibbous, first antennal joint rather stout, slightly curved, somewhat shorter than head and passing its apex by about three-fourths its own length, second joint one-third shorter than first, third twice the length of second (last two joints wanting), rostrum reaching base venter, first joint reaching base of head, second slightly shorter than the last two together. Pronotum with the lateral margins almost straight or very slighly sinuate, their anterior third very obscurely crenulated, humeral angles a little prominent, right-angled. Scutellum subequal in length to head and pronotum together, the postfrenal part distinctly longer than broad, narrowing from the base. Hemelytra slightly passing apex of abdomen, costal margin of corium straight near the base, then ampliately rounded, apical margin straight. Abdomen broader than the hemelytra, beneath somewhat flattened in the middle, but with the ventral furrow only reaching middle of third segment, fourth and fifth ventral segments in the male a little before the median part of the apical margin with a transverse series of stiff hairs arising from minute brown points, sixth male ventral segment

in the middle as long as the two preceding segments together, its basal margin obtusely subangular in the middle, male genital segment constructed much as in *P. ellipticus*, but with the lateral margins of the sinuosity more distinctly rounded. Length, ♀ 13 mm., ♀ 14.5 mm.

Queensland; West Australia.

A very distinctive species, readily recognised by the structure of the head, etc. In the shape of the body it is somewhat similar to *P. edwardsti*, V. Duz., but is still broader and laterally more rounded.

Judging from the various localities it is distributed throughout Northern Australia.

Paramenestheus abditus, n. sp.

Oblong-oval, drab-coloured, above rather thickly punctured with dark fuscous, exocorium appearing lighter owing to its finer and paler puncturing, inner margin of juga, a vitta on clypeus continued to base of head, two broader short basal vittae to head between ocelli and eyes, the pronotal cicatrical areas, a subquadrate callus near basal angles of scutellum on the inner side of the black foveae, a median vitta in basal half of scutellum, two parallel vittae in its apical half not reaching apex and continued divergently from middle of scutellum toward its base, the lateral margins of its postfrenal part the veins of corium and clavus, and a vitta in apical half of mesocorium not far from the radial vein impunctate and generally paler, the postfrenal lateral margins of the scutellum and the radial vein much paler, whitish, a spot at inner end of pronotal cicatrical areas and at apex of scutellum, and a vitta on the mesocorium close to the postero-median part of the radial vein composed of subconfluent blackish points, membrane greyish, the veins scarcely darker, spiracles and extreme basal angles of the ventral segments fuscous, head beneath punctured the same as above, pleurae with two percurrent vittae composed of aggregated blackish points and separated by a rather broad very remotely punctate band, the exterior vitta with closer and darker punctures, and bordered on its outer side with an irregular interrupted impunctate vitta, lateral border of propleurae subbiseriately punctate, venter mostly impunctate, but on each side with a black-punctured posteriorly evanescent vitta forming a continuation of the inner pleural vitta, and with a faint trace of a similar sublateral vitta, sixth ventral segment punctured with fuscous in its

posterior median part; antennae brownish rufescent, their first two joints, the rostrum (except the piceous apical joint), and the legs pale testaceous, femora and (less distinctly) tibiae dotted with fuscous. Head and antennae constructed as in the type of the genus (*P. terricolor* Bredd.), rostrum reaching middle of metasternum, second joint twice longer than the last two joints together. Pronotum at apex distinctly broader than head, apical angles produced in a very short apically truncate lobelet, lateral margins somewhat laminate and a little rounded. Scutellum shaped as in the typical species. Hemelytra slightly passing apex of abdomen. Sixth male ventral segment in the middle as long as the fifth and half the fourth together, its basal margin rounded; male genital segment moderately ascending, the apical margin depressed, trisinuate, the lateral sinuosities very shallow, the median one much deeper. Length, ♂ 9.5 mm.

Queensland.

Apparently coming nearest to *P. semoni*, Horv., but with somewhat shorter head, much darker three last antennal joints, different colour markings, differently sculptured scutellum, and otherwise punctured venter; the male sexual characters are probably also different, but this sex of *P. semoni* is still unknown.

Fam. MYODOCHIDAE.

Getes, n. gen.

Body subovate, beneath transversely strongly convex, somewhat compressed. Head shorter than broad and broader than apex of pronotum, a little longer than anterior lobe of pronotum, immersed to the eyes, clypeus slightly longer than juga, ocelli placed very near the eyes, antenniferous tubercles perpendicularly descending, contiguous to the eyes and ending slightly beneath the level of their lower angle, antennae rather long and slender, all joints linear, first joint passing apex of head by half its length, second twice the length of first, third one-fourth shorter than second, fourth as long as third, thicker than the two intermediate joints, bucculae very short, rostrum reaching middle of metasternum, first three joints subequal in length, fourth shorter, basal joint reaching base of head, longer than first antennal joint. Pronotum trapeziform, twice as broad as head, transversely impressed a little before middle and with a depressed apical collar, all margins straight, only the narrowly sublaminate or, rather, carinate lateral margins very slightly rounded near apex. Scutellum as long as broad, with a

slightly raised smooth median line. Corium with the costal margin straight in its basal fourth, then somewhat ampliately rounded, apical margin straight, shorter than the claval suture, radial vein furcate behind the middle, forming an elongate triangular apical cell; clavus with four rows of punctures and somewhat confusely punctate between the two median rows which join before middle of clavus, proceeding as a single row to its base, the commissure as long as the scutellum. Posterior angles of metapleurae acute. Venter of the female with the fifth segment extremely short in the middle. Front femora a little thicker than the others, unarmed; middle and hind tibiae with a row of spine-like bristles beneath.

This genus does not seem to have any near ally among the described tropical genera, but is closely related to the Mediterranean genus *Hyalochilus*, Fieb., from which it differs in having the eyes a little less prominent beyond the pronotal apical angles, the bucculae shorter, the first antennal joint produced farther beyond the apex of the head, the second joint longer, the fourth not fusiform, the scutellum shorter, the front femora less slender, etc.

Getes fusciceps, n. sp.

Head dark fuscous, clothed with extremely fine and short recumbent white hairs, clypeus testaceous, still paler at the tip, pronotum and corium (with clavus) stramineous, rather thickly and finely punctured with ferruginous or brownish, anterior lobe of pronotum (excepting apical and lateral margins and a longitudinal median line) the abdomen ferruginous, impunctate, pronotal lateral margins testaceous with a small stramineous spot at the ends of the transverse impression, scutellum testaceous, brown-punctured, the median line and a sublateral vitta stramineous, impunctate, the apex fuscous, corium with a faint brownish spot just behind middle of costal border and with the apical angle fuscous, membrane whitish, between the veins with fuscous streaks and spots, pectus piçeous, punctate, propleurae partly paler; antennae, rostrum, and legs testaceous, last antennal joint fuscous, apex of femora stramineous preceded by a fuscous annulation in the two posterior pairs, the spine-like bristles of the four posterior tibiae black. Hemelytra reaching apex of abdomen, corium with the costal border and veins impunctate, near the claval suture with the two ordinary punctulate lines, the smooth space between these lines broadest a little behind the middle and with a few punctures at this place. Length, ♀ 3.8—4.4 mm.

Tasmania.

The hind tarsi are not visible in the carded specimens, but as the first joint of the middle tarsi is only as long as the two other joints combined, it is probably not much longer in the posterior tarsi. In one specimen the pale impunctate sublateral vittae of the scutellum are lacking, but this specimen is abnormally developed also in other respects

Dieuches distanti, n. sp.

Black, clavus (except the black base) fuscous, posterior part of propleurae, and the abdomen castaneous, lateral borders of prothorax from before middle of anterior lobe to a little beyond apex of posterior lobe, an abbreviated median line and a spot on each side of this to posterior pronotal lobe, apex of scutellum a prominent basal streak at exterior margin of clavus and a much shorter streak at the opposite claval margin, basal half of corium (excluding a vitta at middle of claval suture, a median suffusion, and an oblong costal spot, which are fuscous), a large triangular costal spot in apical half of corium, a small spot at exterior basal angle of membrane, and a large rounded apical spot to it, epipleura of corium (except two oblong fuscous spots), posterior angle of metapleura, and a lateral spot to fourth and fifth abdominal segments whitish; antennae, rostrum (except the testaceous two intermediate joints), and legs fuscous, a broad subbasal annulation to fourth antennal joint, trochanters, base of front femora, and a little less than basal half of middle and hind femora whitish. Head impunctate, as long as anterior pronotal lobe, ocelli placed near eyes, first antennal joint a little longer than anteocular part of head and passing the apex by half its length, second joint about double the length of first rostrum reaching middle coxae. Pronotum as long as broad, the laminate lateral margins reaching the base, anterior lobe finely and sparsely punctate, more than one-half longer than the posterior lobe which is rather coarsely and thickly punctate, basal margin straight. Scutellum somewhat indistinctly punctate. Corium in its basal half finely punctured (mostly in rows) with fuscous, the white preapical costal spot finely and sparsely punctate with pale fuscous, its anterior margin transverse, the posterior margin oblique. Prosternum with a conspicuous foveate impression on each side of the base of the acetabular fissure, finely transversely strigose and minutely sparsely punctate, anterior prosternal border and posterior part of propleurae coarsely and thickly punctate.

Abdomen almost glabrous, the pale lateral spot of the fourth segment oblong, that of the fifth subquadrate. Anterior femora moderately incrassated, beneath biseriately spinous almost down their whole length, anterior tibiae in the male armed beneath with about four acute tubercles; intermediate femora (♂) beneath in the basal half with a few spines; first joint of posterior tarsi about three times longer than the two other joints together. Length, ♂ 7.8 mm.

West Australia.

Notable by having (at least in the male) also the middle femora spinous beneath; not nearly allied to any described Australian species. The eyes are red in the type, but this character cannot be relied on in dry specimens.

Named after Mr. W. L. Distant, to whom we owe so much of our quantitative knowledge of the Australian Hemiptera.

Paradrymus, n. gen.

Body ovate, somewhat depressed above, strongly transversely convex beneath, distinctly punctate all over except on the venter. Head broader than apex of pronotum, equal in length to anterior pronotal lobe, very slightly exserted, as long as broad, clypeus conspicuously produced beyond the juga, eyes globose, strongly prominent, but not large, the very small ocelli placed behind the level of the posterior margins of the eyes, about as far from them as from the median line of the head, the space between eyes and apex of antenniferous tubercles a little shorter than the eyes, bucculae small, rounded, throat horizontal, antennae long and slender, first joint passing apex of head by about one-third its length, second the longest, third and fourth subequal in length, each of them longer than first, rostrum slender, reaching beyond hind coxae, first joint distinctly longer than first antennal joint, almost reaching base of head, second subequal in length to the last two put together, third much longer than fourth. Pronotum subgradually narrowed from base to a little beyond middle, then more strongly rotundately narrowed to apex, transversely distinctly impressed somewhat behind the middle, at apex with a distinct but narrow linear collar, at base more than two times broader than head, lateral margins narrowly laminate but more broadly so at the ends of the transverse impression where they are angularly dilated inwards and very slightly sinuate exteriorly, basal margin almost straight, anterior lobe somewhat convex, pos-

terior lobe with a longitudinal impression in the middle of its anterior half. Scutellum equilaterally triangular, its basal half with a triangular, medially somewhat impressed elevation emitting a keel to the apex. Prosternum about as long as meso- and metasternum together; posterior margin of metapleura straight, forming a right angle with the lateral margin. Hemelytra entirely covering the abdomen, corium with the median vein distinct in its apical part, obliterated toward the base, the costal margin straight in its basal third, then somewhat ampliately rounded, apical margin straight, shorter than the claval suture, clavus with three rows of punctures, its commissure shorter than half the length of the scutellum, the next inmost vein of the membrane curved strongly inwards in its basal half. Abdomen with the connexivum reflected, the sutures of the three basal ventral segments crenulate, fourth segment anteriorly with two sublateral glandular spots but with no such spot near the posterior margin, sixth male ventral segment deeply emarginate at apex with the apical angles very acute, male genital segment with a small oblong tubercle near apex. Front femora incrassated, beneath in the whole apical half longitudinally impressed, the impression terminated on its anterior side by a row of very small thick-set teeth with one much larger tooth in the middle of the row, in the male moreover provided with a small tubercle at the basal end of the impression; all tibiae almost bare, without spine-like bristles, front tibiae straight, in the female triangularly a little dilated at apex, much more strongly so in the male, which has the dilatation angularly inflected and armed with a spur beneath; first joint of hind tarsi about one-half longer than the two other joints together.

This genus is on the whole more related to *Drymus*, Fieb., which is chiefly represented in the Palearctic region, than to any other described genus, and in its general aspect it is also rather similar to that genus, from which it differs mainly by the longer head with more projecting clypeus and longer rostrum, by the structure of the scutellum, the differently curved costal margin of the corium, the lack of distinct foveae in front of the fore acetabula, the shape of the sixth male ventral segment, and the somewhat differently armed fore femora.

PARADRYMUS EXILIROSTRIS, n. sp.

Black, finely and very thickly subgranularly punctate, posterior lobe of pronotum and sometimes corium pale testaceous, somewhat less densely punctured with fuscous, but corium usually

fuscous with two spots on exocorium and three spots (one median and two apical) on mesocorium testaceous, the apical and the narrow laminate lateral margins of pronotum dark testaceous, paler at the ends of the transverse impression, membrane fuscous, the veins and a few more or less distinct spots testaceous, abdomen beneath indistinctly punctulate, its lateral borders paler, sometimes the whole venter brown, antennae fuscous, apical half of last joint (except extreme apex) pale testaceous, rostrum and legs testaceous, femora fuscous. Second joint of antennae not quite twice, and third joint one-half longer than first. Rostrum nearly reaching apical margin of second ventral segment. Pronotum more than one-half broader than long. Hemelytra reaching apex of abdomen. Sixth male ventral segment in the middle somewhat longer than fifth. Length, ♂ ♀ 4.8—5.6 mm.

Queensland; Victoria.

TAPHROPELTUS AUSTRALIS, n. sp.

Head black, finely and very thickly punctate, slightly longer than anterior pronotal lobe, the postocular part very short, antennae rather stout, a little longer than half the length of the body, the first two joints testaceous, second two-thirds longer than first, the last two joints fuscous, third a little shorter than second, fourth as long as third, reddish at apex, rostrum testaceous, reaching middle of mesosternum. Pronotum distinctly transversely impressed behind middle, anterior lobe black, finely and very thickly punctate, with a round foveate median impression before the base and on each side between this and the lateral margins with a smaller somewhat obsolete foveola, almost one-half longer than the posterior lobe which is stramineous, finely and more sparsely punctulate with brown, longitudinally slightly impressed in the middle of its anterior half, with five dark fuscous vittae, one in the middle and two oblique ones on each side starting from the same point near the humeral angles, the narrowly laminate not sinuate pronotal lateral margins whitish. Scutellum black, finely punctulate, the apex, the apical end of the median keel, and a lateral vitta white, these vittae beginning a little before the middle and becoming narrowly linear posteriorly where they join the apex. Corium and clavus stramineous, the former almost impunctate, only in the basal half (mostly along the veins) with a few very small brownish punctures, the veins, a somewhat sinuous submedian fascia (not entering the clavus), and an oblong spot at the apical angle dark fuscous, the two ordinary punctured lines near the claval suture,

and the two exterior ones of the three similar claval lines placed extremely close to each other both on the corium and on the clavus, all these five lines composed of very small points; membrane variegated with whitish and fuscous, the veins pale. Body beneath piceous, almost impunctate, acetabula pale ferruginous. Legs stramineous, all coxae and the fore femora pale ferruginous, the latter with a spine a little in front of the middle and a row of very small teeth between the spine and the apex, fore tibiae almost straight. Length, ♀ 3 mm.

Victoria.

This fine little species is somewhat similar to the Mediterranean *T. nervosus*, Fieb., but the posterior pronotal lobe is more marked with fuscous vittae, the antennae are differently coloured, etc.

The genus *Taphropeltus*, Stäl, was hitherto known only from the western Palearctic region, but seems to be widely dispersed in the Old World. I have an undescribed *Taphropeltus* from Java, and *Scolopostethus putoni*, B. White, from New Zealand, probably belongs here, as Buchanan White compares it with *Sc. contractus*, H. Sch., which is a *Taphropeltus*.

Myocara, n. gen.

Body elongately ovate. Head a little shorter than pronotum, slightly broader than the pronotal apical collar, but a little narrower than the pronotum just behind the collar, immersed almost to the eyes, impunctate, distinctly longer than broad, the anteocular part also longer than broad, triangularly produced in front of the antennae, acute at apex, clypeus scarcely longer than juga, the space between eyes and base of antennae shorter than an eye, the small ocelli almost contiguous to the eyes, throat horizontal, bucculae very short, semicircular, antennae rather long and slender, first joint passing apex of head by half its length, second twice as long as first, third somewhat shorter than second and a little longer than fourth, which is not thicker than the others, rostrum reaching far beyond base of venter, first joint as long as first antennal joint, but not reaching base of head. Pronotum (in the brachypterous form) but a little broader than long, at the base almost twice broader than head, gradually a little narrowing from the base to near apex, where it is rather strongly roundedly narrowed to the depressed collar which is separated from the impunctate anterior pronotal lobe by an impressed punctate line, the lateral margins narrowly depressed, not sinuate, apical and basal margins straight, the somewhat convex anterior lobe twice as long as the thickly punctate

posterior lobe which is depressed, especially in the middle. Scutellum distinctly longer than broad, almost flat, punctate. Hemelytra in the brachypterous form reaching base of last dorsal segment, apical margin of corium rounded, clavus and basal half of corium coarsely and thickly punctate, apical half of corium more superficially and sparingly punctate, clavus with the puncturation arranged in four rows, the commissure as long as the scutellum, radial vein only reaching middle of corium, basal half of exocorium with a single row of close punctures, the apical half fused with the mesocorium owing to the abbreviated radial vein, membrane rudimentary, appearing only as a narrow coriaceous strip attached to the apical margin of the corium. Pectus punctate. Abdomen impunctate, last female dorsal segment with the apical margin angularly sinuate in the middle, fourth ventral segment with two sublateral glandular spots near base and a third one behind the middle, fifth female, ventral segment very short in the middle. Front femora somewhat incrassated, beneath in the apical half with two small spines; middle and hind tibiae with a few stiff bristles; first joint of hind tarsi twice as long as the two other joints together.

Type: Rhyparochromus acuminatus, Dall.

Allied to the Neotropical genus *Esuris*, Stål (as represented by its type[1]), from which it differs by the very long rostrum, the longer scutellum, the much longer hind metatarsus, and by having the radial vein of the corium very distinct in its basal half; from the Indian genus *Lua*, Dist., it is distinguished by the less incrassated and less convex subglabrous body, the narrower, apically more pointed head, the much less transverse pronotum, the narrower scutellum, the (basally) very distinct radial vein, and by having the basal joint of the antennae produced much beyond the apex of the head.

The species upon which this genus is founded has stood for many years in our catalogues among the "species incerti generis," and Distant says nothing of it in his revision of the Hemiptera of the British Museum, although he must have seen the type.

Myocara acuminata, Dall.

Queensland.

Apart from some generic characters detailed above, I have little to add to Dallas's description which fits the specimen before me so well that I feel sure of the identity.

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1 The Guatemalan *E. purpurata*, Dist., is possibly an *Esuris*, but that the North American *E. astanea*, Barb., does not belong to this genus is clear from several characters.

The impressed points of the upper side of the body bear a very small round whitish scale, visible only when viewed vertically from above. The last antennal joint, which is missing in Dallas's type, is pale testaceous. The tergum of the abdomen and the female genital segment are castaneous. The apex of the femora is of the same testaceous colour as the tibiae and tarsi. The male is still unknown.

I know only the brachypterous form of this insect, but Dallas had before him both this form and an immature specimen of the macropterous form. Although he does not mention it, I suppose that the macropterous form has the pronotum somewhat broader at the base with comparatively shorter anterior lobe, the ocelli a little larger, and the corium less rounded at apex. It is probable that *Esuris* and *Lua* also are pterygo-dimorphous, as the Australian genus *Euander*, Stål, has proved to be.

Fam. HENICOCEPHALIDAE.

SYSTELLODERES AETHERIUS, n. sp.

Smooth, shining, subglabrous, darkish testaceous, hemelytra and abdomen opaque, the former fuscous, the latter greyish brown, somewhat mottled with pale testaceous, pubescent, more longly pilose at and near apex, rostrum and legs pale testaceous, sparingly shortly pilose. Head as long as the pronotum in the middle, basal lobe slightly broader than long and a trifle broader than the width across the eyes, somewhat flattened, its lateral margins moderately rounded, eyes small, antennae about as long as head and half the pronotum together, very slightly pilose, first joint very short, the three following joints equal in length, each as long as the basal lobe of the head. Pronotum a little longer than broad, basal margin rather deeply arcuately sinuate, apical lobe a little broader than head, with an extremely fine impressed longitudinal line in the middle, median lobe one-third (♂) or one-fourth (♀) narrower than basal lobe, in the male subequably rotundately narrowing toward apex, in the female subparallel from base to beyond middle, then rather suddenly narrowed, in the middle with a longitudinal impression not widening posteriorly and not quite reaching the base. The basal margin in the middle somewhat produced backwards over the apical part of the basal lobe, which is almost three times longer at the sides than in the middle, slightly (♀) or more distinctly (♂) narrowed from base to apex. Scutellum broader than long, somewhat flattened, the lateral margins straight. Heme-

lytra a little shorter than the abdomen. Legs short, fore femora rather strongly incrassated, about $2\frac{1}{2}$ times longer than broad, above longitudinally convex, beneath straight, fore tibiae gradually widened from the base to the apex where they are but little narrower than the femora at their greatest breadth, hind femora shaped almost as the front femora and not longer, but slightly narrower and a little more compressed, reaching middle of venter, hind tibiae a little shorter than the femora, subparallel from apex to near middle, then strongly narrowed toward the base. Length, ♂ ♀ 3.3 mm.

Queensland.

The genus *Systelloderes* is new to Australia, but is probably of the same world-wide distribution as *Henicocephalus*. It is represented in the Neotropical region by a few (partly undescribed) species, in North America by one, and in Europe by one species. No species has hitherto been recorded from Africa or Asia, but I know an undescribed species from the Philippine Islands, and the insect described by Enderlein from Crozet Island under the name *Phthirocoris antarcticus* is doubtless the larva of a *Systelloderes*.

Fam. REDUVIIDAE.

ONCOCEPHALUS QUOTIDIANUS, n. sp.

Pale testaceous, head above and pronotum with the typical linear fuscous markings and black ocellar spot, a broad lateral vitta to head and two narrow vittae on the throat between the eyes fuscous, scutellum (except the apical process) black, hemelytra with the same fuscous markings as in *O. confusus*, Reut. (and most other species), but with the ground-colour paler down the middle of the corium and in the basal part of the exterior membranal cell, connexivum with two fuscous lines, the outer line placed immediately within the lateral margin, breast and venter typical in colour and markings, close to the ventral lateral margin a narrow fuscous vitta which is somewhat darker and a little dilated just before the apical angles of the segments; antennae testaceous, first joint (except basal part) tinged with pale fuscous, apex of second and the whole third and fourth joints fuscous; rostrum fuscous, beneath, first joint also above, and second joint around the base pale testaceous; legs whitish testaceous, fore and middle coxae irrorated with fuscous, hind coxae with four shining black vittae, the three interior ones confluent at the base, the outermost vitta much shorter than the others and not reaching the base, front femora densely mottled with

pale fuscous, beneath with two dark fuscous vittae, middle and hind femora rather broadly fuscous at apex, front tibiae with a subbasal, a submedian, and an apical fuscous annulation, middle and hind tibiae with an incomplete annulation very near the base and the extreme apex fuscous, but with no trace of the fuscous ring placed before the middle in almost all other species, the tarsi fuscous at apex. Head with the anteocular part a little longer than the remainder, eyes viewed from above hemispherical, as long as broad, their anterior and posterior curvatures equally strong, seen from the side (in the ♂) occupying almost the whole height of the head, the throat between the eyes as broad as the base of the first rostral joint, antennae (♂) with the first joint as long as the distance between its base and the ocelli, above with very few and short semidecumbent hairs, beneath glabrous, second joint twice the length of first, linear, shortly semierectly pilose, still more shortly and sparingly so toward the base, first and second rostral joints equal in length. Pronotum as long as broad, with a lateral tubercle somewhat in front of the transverse impression, the apical margin distinctly angularly sinuate, the tubercle of the apical angles directed outwards and somewhat upwards, its anterior margin transverse, the posterior margin obliquely sinuate, the lateral margins granulated between the apical and lateral tubercles, the pronotal lobes subequal in length, anterior lobe slightly, posterior one twice broader than long, the humeral angles acute, slightly prominent. Scutellum slightly recurved at apex. Prosternum with the apical spinules short, curved. Fore trochanters with about three small teeth, fore femora as long as pronotum and postocular part of head together and three times longer than broad, beneath with about eleven teeth and two setiferous granules between each pair of teeth, the superior subbasal sinuosity broad and rather shallow, fore tibiae reaching trochanters, fore tarsi less than one-third the length of tibiae; hind femora somewhat passing apex of abdomen (♂), a little shorter than the tibiae. Length, ♂ 14 mm.

Victoria.

Allied and very similar to *O. confusus*, Reut., but smaller and narrower, and with the anteocular part of the head a little longer, the eyes seen from above shorter and more globular with their anterior and posterior curvatures equally strong (in *confusus* longer than broad with the anterior curvature less pronounced), the throat broader between the eyes, the second antennal joint perceptibly shorter and more shortly setose, the fore tarsi shorter, and the posterior legs quite differently coloured.

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ART. II.—*Heteropterous Hemiptera collected by Professor W. Baldwin Spencer during the Horn Expedition into Central Australia.*

BY DR. E. BERGROTH, C.M.Z.S., LOND.

(Communicated by Professor W. Baldwin Spencer, F.R.S.)

Before the expedition to Central Australia, organized and equipped by Mr. Horn twenty years ago, no Hemiptera (and scarcely any insects at all) were known from those regions. The collections brought home by the expedition are therefore of unusual interest. The Hemiptera are not represented by a great number of species, nor could they be expected to be so, considering the aridity of the territory. More recently Central Australia has been visited by Mr. H. J. Hillier, whose collections are now in the British Museum. They were made east of Lake Eyre, whereas the Horn expedition explored the tracts west and north-west of this lake. Of the Hemiptera collected by Mr. Hillier some new species, mostly Pentatomidae (three of which were also found by the Horn expedition), have been described by Mr. Distant, but so far as I know he has not yet published any list of all the collected species.

Fam. THYREOCORIDAE.

1. ADRIŠA, sp.

Crown Point.

Allied to *A. mayri*, Sign., but probably distinct.

Fam. SCUTELLERIDAE.

2. CHOEROCORIS PAGANUS, Fabr.

Illamurta, James Range.

Fam. PENTATOMIDAE.

3. OECHALIA CONSOCIALIS, Boisd.

Stevenson River.

4. ONCOCORIS DESERTUS, n. sp.

Oval, pale ochraceous, beneath still paler, whitish, a small spot at outer basal angle of connexival segments and at base of acetabula, two small widely separated basal spots to fourth and fifth

ventral segments, spiracles, scattered dots to femora, and the stridulatory spicula of the hind femora brown, membrane pale greyish with whitish veins, last rostral joint, except base, pitchy black; above finely and sparsely punctured with brown but with impunctate areolets here and there, connexivum almost concolorously punctulate; beneath more palely and, on the venter, more finely and remotely punctulate, the latter with its middle part and lateral borders (as far as the spiracles) impunctate; at exterior end of pronotal cicatrical areas, behind interior part of these, at basal angles of scutellum, and in each pleura with a small cluster of dark fuscous punctures. Head slightly shorter than its breadth and than the pronotum in the middle, a little incised at apex between juga and clypeus, first antennal joint scarcely reaching apex of head, second a little longer than third which is pale ferruginous above toward the tip (last two joints wanting), rostrum slightly passing hind coxae. Pronotum 2¼ times broader than long in the middle, lateral margins straight, only behind the apical angles a little sinuate, lateral angles obtuse, scarcely prominent. Scutellum with a small elevated impunctate callus at basal angles. Hemelytra somewhat passing apex of abdomen. Male genital segment with the apical margin sinuate in the middle and with the apical angles slightly callose. Length (excl. membrane), ♂ 8 mm.

Illamurta, James Range.

A very pale, finely punctured species, easily recognisable from the others.

N.B.—The genus *Kalkadoona*, Dist., from Central Australia, which Distant placed among the true Pentatominae, belongs to the division Platycoriaria of the subfamily Halyinae. It has the typical ventral stridulatory vittae of that group and is closely related to *Oncocoris*, Mayr. I saw the type of *Kalkadoona centrimaculata*, Dist., in the British Museum.

5. Alcaeus hermannsburgi, Dist., Ann. Mag. Nat. Hist. (8) VI., 373 (1910) [*Muritha*]; Bergr., Ent. News. XXIII., 23 (1912).[1]

Crown Point; near Storm Creek; Charlotte Waters; Stevenson R.

6. Eumecopus superbus, Dist.

Paisley Bluff, Macdonnell Range.

1 Bibliographical references are here appended only to the species not included in the "Catalogue des Hémiptères" of Lethierry and Severin or in Kirkaldy's Catalogue of the Pentatomidae.

7. Eumecopus y-nigrum, n. sp.

Elliptical, ochraceous, above (excluding head) and on the pleurae and epipleurae rather densely but irregularly punctured with brown, the punctures placed in a network of dark ferruginous tortuous lines, three small basal spots to scutellum, the apical half of its postfrenal part, and a spot behind middle of corium impunctate or almost so, head above with four longitudinal brown or dark ferruginous bands, the inner ones of which are in their apical half (rarely throughout) longitudinally divided by ochraceous, and beneath on each side with three similar bands, the outermost being in its basal half (between eyes and base of antennae) broader and partly visible from above, scutellum with a large black **Y**-shaped marking reaching the middle of the postfrenal part where it occupies the whole breadth of the scutellum, the anterior branches of this figure exteriorly not quite reaching the lateral margins, anteriorly reaching the basal fourth of the scutellum, connexival segments with a transverse brown spot at base and apex, their apical angles ochraceous tipped with brown or entirely brown, membrane brownish, basal and outer borders black, the veins whitish grey, evaporative area of metapleurae greyish brown, abdomen beneath on each side with a broad purplish brown or dark fuscous band outwardly reaching a little beyond the spiracles and emitting a transverse fascia to the lateral margin along the basal and apical margins of the segments, the disk between the longitudinal bands sparingly punctured with brown and on the sixth segment usually with a brown median vitta, basal half of male genital segment dark brown or black, lobes of female genital segment more or less spotted with fuscous; antennae fuscous or blackish, the two first joints reddish brown, all or at least the last three joints at base and second joint at apex yellowish testaceous, rostrum and legs ochraceous, last joint of the former piceous, some streaks and spots to femora, more than apical half of tibiae and their whole upper lateral keels purplish brown, apex of last tarsal joint reddish. Head almost as long as the pronotum in the middle and as broad as long, the ochraceous parts impunctate, the dark vittae finely punctured, antennae five-jointed, first joint two-thirds the length of head and passing apex of head by more than its half, second subequal in length to first, somewhat nodosely dilated at base, third not quite twice the length of second and well separated from it by a distinct articulation, fourth slightly shorter than third, fifth a little longer than second, rostrum somewhat passing middle of

third ventral segment or (usually) reaching base of fourth. Pronotum with the somewhat sinuate lateral margins finely serrulated from apical angle to beyond middle, the short humeral spines directed outward. Hemelytra passing apex of abdomen. Abdomen beneath broadly but not deeply grooved from its base to apex of fifth segment; apical margin of male genital segment on each side with two subconical processes separated by a deep incision, the middle of the margin with a short triangular process preceded by two tubercles and not reaching the apex of the two acute convergent appendages which protrude from the interior of the segment; last female ventral segment at middle of apical margin and female genital lobes palely setose. Length (excl. membrane), ♂ ♀ 20—22 mm.

Var.: membrane whitish hyaline, its basal border brown.

Bagot's Creek; Alice Springs; River Finke near Horse-shoe Bend; Stevenson R.; Dalhouse Springs.

A very distinct species to be placed in Stål's group *d*. The males of this species are not smaller than the females.

8. Eumecopus horni, n. sp.

Elliptical, ochraceous, six percurrent longitudinal punctulate stripes to upper side of head brownish ferruginous, lateral borders of pronotum (excluding extreme margins from apex to beyond middle), a percurrent median pronotal vitta, lateral areas of scutellum (except middle part of margins), a subangular vitta behind middle of mesocorium, and connexivum black, the latter with a few small subconfluent spots at base and apex of the segments, the lateral margins and apical angles ochraceous; membrane fuscous, basal and exterior borders black, the veins greyish white; pronotum, scutellum, and corium punctured with dark fuscous, more thickly and confluently so on pronotum and scutellum, pronotal cicatrical areas almost impunctate and emitting an impunctate streak to the apical margin, scutellum with an oblong callose spot near basal angles and a smaller basal median spot impunctate, the apical half of its postfrenal part very sparingly almost concolorously punctulate; head beneath on each side with three fuscous longitudinal bands, the outermost in its basal half broader and partly visible from above, the two inner ones narrow and composed of close-set punctures; pleurae and venter punctured with fuscous, the latter with the broad lateral borders (not quite reaching the spiracles) and three discal longitudinal bands impunctate, a per-

current sublateral ventral vitta, an oblong median spot to the sixth segment, and spots to the female genital lobes dark fuscous; antennae fuscous, irrorations to upper side of first joint and a rather narrow basal annulation to third joint ochraceous (fourth joint wanting); rostrum and legs ochraceous, last joint of the former black, numerous small round spots to femora mostly arranged in rows, and tibiae, except a median annulation, fuscous (hind legs wanting). Head one-fourth longer than broad and subequal in length to the pronotum in the middle, clypeus conspicuously surpassing apex of juga, first joint of antennae as long as anteocular part of head and passing its apex by about half its length, second joint more than twice the length of first, cylindrical, not at all incrassated in its basal part, third joint above one-third shorter than second, rostrum reaching middle of fifth ventral segment, second joint longer than third and fourth taken together. Pronotum with the lateral margins slightly sinuate in the middle, serrulate in their anterior half, the short humeral spines directed outwards. Scutellum with a foveolate impression in the basal angles. Hemelytra passing apex of abdomen by about one-third the length of the membrane. Abdomen beneath deeply grooved from its base to the apex of the fifth segment. Length (excl. membrane), ♀ 19 mm.

Alice Springs.

The antennae are incomplete in the type, but from the great length of the second joint there can be little doubt that they are four-jointed. The species is related to *E. armatus*, Fabr., but is at once distinguished by the structure of the antennae. It is not impossible that *E. calidus*, Stäl (nee Walk.) belongs to *horni*.

9. Eumecopus eyrei, Dist. Mag. Nat. Hist. (8) VI., 378 (1910).

Crown Point; Illamurta, James Range; Finke River near Horseshoe Bend; Stevenson R., Sullivan Creek.

Crown Point; Illamurta, James Range; Finke River near Bend; Stevenson River.

This species, which is known to me also from West Australia, is easily recognised from the good description, but it is not allied to *E. vittiventris*, Stäl, as Distant says, belonging in fact to another group of the genus and coming very near *E. fuscescens*, Stäl. The second antennal joint is somewhat variable in length, being sometimes, as in Distant's type, little more than one-third the length of the first joint, but usually at least one-half its length; the

fifth joint, which was lacking in the type, is a little shorter than the fourth and of the same colour. The male genital segment is similar to that of *E. fuscescens*.

10. Poecilometis spenceri, n. sp.

Suboval, ochraceous, four longitudinal stripes to upper side of head (the exterior ones narrowing in the anteocular part), an oblong spot behind middle of corium at apex of rimula, membrane (except the greyish white veins), a lateral vitta to head under the margin, a vitta in the anterior half of the propleurae, spiracles, a median streak to sixth ventral segment, and last joint of rostrum and of tarsi black, the first two antennal joints ochraceous sprinkled with small fuscous points, blackish on their outer side (except apex of second joint), third joint blackish excepting base and apex (last two joints wanting); above rather thickly and strongly but not uniformly punctured with black, the puncturation becoming denser in seven percurrent stripes on the pronotum (the three median ones parallel, the outermost placed immediately within the lateral margin), in the narrow basal part of the exocorium, and in an oblong area before middle of mesocorium close to the cubital vein, whereas an anteriorly three-branched scutellar vitta (posteriorly reaching a little beyond the frena), a narrow area interiorly bordering the rimula, a spot behind middle of mesocorium near cubital vein, and a somewhat waved vitta behind the rimula are but sparingly punctured, a percurrent median stripe to head, two stripes to vertex between the ocelli, a median line on anterior half of pronotum, the pronotal lateral and basal margins, a callus at basal angles of scutellum, anterior half of costal margin, apical margin and veins of corium, and exterior margin of connexivum impunctate; beneath less strongly and somewhat less thickly punctured with black, the puncturation getting thinner in the middle of the venter; femora and tibiae rather densely dotted with black. Head as long as broad and one-fourth shorter than the pronotum in the middle, first antennal joint as long as head and passing apex of head by about four-fifths its length, second joint somewhat shorter than first, third as long as first, rostrum reaching a little beyond base of abdomen. Pronotum with the slightly sinuate lateral margins bluntly crenulated in their apical third, the lateral angles subacutely a little prominent with a small sinuosity behind the angles. Hemelytra reaching a little beyond abdominal apex. Abdomen with apical angles of sixth segment shortly and acutely triangularly

produced backward, ventral furrow very distinct, reaching apex of fifth segment, but much shallower in fourth and fifth segments. Length, ♀ 18.5 mm.

Alice Springs.

In this very distinct species the apical angles of the sixth abdominal segment are shortly spinously produced as in the genus *Eumecopus*, but on account of the short head and the only subacutely prominent, not spinous, humeral angles it must be referred to *Poecilometis*, with which it also agrees in its general aspect.

11. Cephaloplatus nubifer, n. sp.

Oval, somewhat convex, about one-half longer than its greatest width, testaceous, paler beneath, a narrow impression at basal angles of scutellum and a spot at basal angles of connexival and ventral segments black, middle of sterna, a curved vitta to pleurae, spiracles, ventral sutures in the middle, and last rostral joint piceous, in specimens with well pronounced colouring a waved fuscous transverse line between pronotal humeral angles; membrane dull greyish with fuscous veins and spots; moderately thickly but somewhat irregularly punctured with fuscous, the laminately expanded lateral borders of the prothorax more remotely and coarsely punctate, connexivum very remotely punctured, a spot behind middle of corium, a rather narrow median vitta to venter, and ventral lateral borders impunctate, pronotum, scutellum, and corium with clusters of thick-set punctures, four of these clusters placed in a transverse row before middle of pronotum, four at basal margin of scutellum, one at scutellar lateral margins before their middle, and three in the corium placed successively, the hindmost at the apical margin; almost the whole front femora, apical part of middle and hind femora, and upper side of all tibiae sprinkled with round fuscous spots. Head as broad as long, a little incised at apex, lateral margins in front of eyes with an angular prominence directed outwards, then rounded, juga contiguous in front of clypeus, rather narrowly rounded at apex, second antennal joint a little passing apex of head, with an obscure dark annulation before the tip (last three joints wanting). Pronotum in the middle as long as head, apical angles subacutely produced forwards, reaching (in the normal position of the head) a little beyond anterior margin of eyes, lateral margins scarcely or very minutely crenulated, slightly sinuate behind middle and with a small indentation immediately behind apical angle, lateral angles obtuse, a little prominent. Scutellum somewhat granulated (more distinctly so

when seen in profile), laterally distinctly sinuate behind middle, postfrenal part but slightly narrowing from its base and as broad as long, comparatively broadly rounded at apex. Hemelytra almost or quite reaching apex of abdomen, costal margin of corium obscurely crenulate in its basal part, membrane rather small, half the length of corium. Abdomen with the apical angles of the segments bluntly prominent, male genital segment with the apical margin obtusangularly sinuate, its apical angles slightly prominent. Length, ♂ 9.5—10 mm.

Macdonnell Range; Alice Springs.

Not closely allied to any previously described species. I have also seen an undetermined specimen of it in the British Museum.

N.B.—In the males of *Cephaloplatus*, which were unknown to Stål, the sixth ventral segment is rounded at the base, not angular as in the allied genus *Dictyotus*, Dall.

Hypolcus, n. gen.

Body oval, somewhat depressed. Head about as broad as long and almost as long as pronotum in the middle, a little convex, lateral margins subacutely narrowly carinated, rotundately angular, scarcely or very slightly sinuate behind middle, clypeus parallel in its basal half, then narrowing toward the tip, juga a little longer than clypeus, but neither meeting nor convergent in front of it, subacute at apex, ocelli about three times more distant from each other than from the eyes which are rather small but prominent, touching apical margin of pronotum (in the normal position of the head), narrowly oval when seen obliquely from before, their vertical diameter being much longer than the horizontal, interocular space over four times broader than an eye, antenniferous tubercles small, not visible from above, antennae five-jointed, first joint very short, little more than twice longer than broad, the three following joints on the whole subequal in length though somewhat variable in this respect, second not quite reaching apex of head, fifth a little longer than fourth, the four last joints successively increasing in thickness, bucculae low, percurrent, neither ampliated nor angular at anterior end, rostrum reaching beyond hind coxae, first joint slightly passing bucculae, second shorter than the last two together, third shorter than second but longer than fourth. Pronotum with the apical margin neither elevated nor levigate, rather deeply arcuately sinuate behind interocular space of head, truncate behind eyes, lateral margins not or very obscurely crenulated, not reflexed but laminately dilated, gradually more widely so toward the apical

angles which are produced forward in a subtriangular, apically subtruncate lobe almost reaching or slightly passing the level of the anterior margin of the eyes, lateral angles subrotundate or obscurely notched, not prominent, postero-lateral and basal margins straight. Scutellum a little longer than broad and about as long as pronotum and head together, with a small levigate callus near basal angles, lateral margins a little sinuate almost in the middle, frena scarcely passing middle of scutellum, the postfrenal part of which is a little longer than broad, gradually somewhat narrowing from its base to the rounded apex. Hemelytra slightly passing apex of abdomen, rimula reaching far beyond middle of corium, the apical margin of which is straight or very slightly sinuate before apical angle, membrane with simple veins. Sterna longitudinally grooved in the middle; metasternal orificia not produced in a fold or furrow. Abdomen beneath furrowed in the middle, unarmed at base, apical angles of the segments scarcely prominent. Tibiae above flattened and margined.

Allied to *Lubentius*, Stål, from which it differs in the structure of the head and pronotum.

12. Hypolcus apricus, n. sp.

Above black or dark fuscous, thickly punctured, the dilated lateral borders of the pronotum, the calli at the basal angles of the scutellum, a small basal median spot to it, a semicircular concolorously punctate spot occupying its apex, base of exocorium, a spot behind middle of corium at apex of rimula, several mottlings to pronotum, scutellum, and corium, basal and lateral borders to abdominal tergum, connexivum from its base to beyond middle of second segment, and an interiorly rounded median lateral spot to the remaining connexival segments ochraceous; beneath testaceous, a spot at basal and apical angles of ventral segments, spiracles, and an interior apical spot to female genital basal lobes fuscous or pitchy black, pectus moderately densely and rather strongly punctured with fuscous, head and venter more finely and, especially in the male, thickly punctulate with fuscous, rather roughly or granularly so on venter owing to the anterior margin of the small points being elevated, an interiorly rounded lateral spot (smaller but more sharply defined in the male) to ventral segments without the fuscous puncturation; antennae black, first joint and usually the articulations (very narrowly) of the other joints testaceous; rostrum and legs testaceous, the former darkened at apex, two usually broad and subconfluent annulations to apical half of

femora, a subbasal and broad apical annulation to tibiae, and the tarsi fuscous. Rostrum reaching middle of third ventral segment. Pronotum with the lateral margins almost straight. Ventral furrow deep from its base to apex of fourth segment, narrow and very shallow in the last two segments; male genital segment with a triangular median impression, apical margin sinuate in the middle. Length (excl. membrane), ♂ 8.5—9 mm., ♀ 9.5—10 mm.

Crown Point; Finke River near Horse-shoe Bend; Dalhousie Springs. Idracowra.

13. TURRUBULANA PLANA, Dist. Ann. Mag. Nat. Hist. (8) VI., 386 (1910); Bergr., Ent. News XXIII., 25 (1912).

Stevenson River.

In the above quoted paper I have made some remarks on the characters and systematic position of this insect. It has a superficial resemblance to a miniature *Atelocera* (near which Distant placed it), but there is no real relationship between these two genera.

The monotypic genera *Lubentius*, *Hypolcus*, and *Turrubulana* form a well defined little group not represented outside the Australian continent. They may be distinguished as indicated below.

1 (4) Head about as long as broad, not longer than pronotum in the middle, anteocular part moderately narrowing from base to apex, laterally more or less distinctly unisinuate. Apical margin of pronotum neither levigate nor elevated . .

2 (3) Head rounded at apex owing to juga and clypeus being equal in length; bucculae rather high. Lateral margins of pronotum narrowly depressed throughout, at apex with a short blunt tooth directed outwards - - *Lubentius*, Stål.

3 (2) Head shortly bicuspidate at apex owing to juga being longer than clypeus; bucculae low. Lateral margins of pronotum rather broadly laminately depressed, gradually more broadly so toward the apex, which is subtriangularly lobately produced forwards to about the level of anterior margin of eyes - - - *Hypolcus*, Bergr.

4 (1) Head one-half longer than broad and longer than pronotum in the middle, anteocular part strongly narrowing from base to apex, laterally bisinuate. Apical margin of pronotum levigate and subelevated behind interocellar space of head. Lateral margins of pronotum as in *Lubentius* - - - - *Turrubulana*, Dist.

Distant has described an Australian genus *Pseudaelia* which he says is allied to *Lubentius*, but from its characters—especially the structure of the rostrum and abdomen—it is evident that it is only distantly related to this genus and cannot be placed in the same group.

14. PIEZODORUS RUBROFASCIATUS, Fabr.

Alice Springs.

PETALASPIS, n. gen.

Body obovate, convex before middle, the head and the anterior part of pronotum being rather strongly declivous in the same plane. Head a little broader than long, narrowing toward the rounded apex, laterally moderately sinuate, clypeus scarcely longer than juga, subparallel, eyes rather large but not much projecting, ocelli four times more distant from each other than from eyes, antenniferous tubercles partly visible from above, antennae five-jointed, first joint not reaching apex of head, bucculae percurrent, rostrum somewhat passing hind coxae, first joint as long as bucculae, second scarcely longer than third, fourth slightly shorter than third. Pronotum at apex as broad as head, the area between the non-elevated apical margin and the cicatrical areas still more thickly and finely punctulate than the remainder of the disk, lateral margins obtuse, broadly and slightly sinuate, humeral angles a little prominent, right-angled, postero-lateral margins sinuate before base of corium, basal margin rather deeply sinuate. Scutellum with straight lateral margins and frena reaching far beyond its middle, acute at apex but with a laminate appendage horizontally projecting on each side from under the apical part; this appendage beginning immediately behind the frena, slightly narrowed from the base to its subtruncate apex and extending backwards beyond the true apex of the scutellum (cf. fig. 1). Hemelytra but little passing apex of abdomen, corium with slightly rounded apical margin, membrane with numerous simple veins. Metasternum with a robust median ridge raised above the level of the coxae, sinuate posteriorly for reception of the ventral basal tubercle, and continued forwards to apex of prosternum, being narrower but roundedly more raised under the prosternum and obliquely subtruncate at apex. Abdomen beneath (♂) roof-shaped, armed at base with an acute tubercle directed forwards, apical angles of the

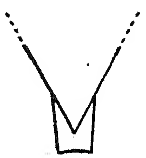

Fig. 1.

segments acutely a little prominent, each of the two male genital segments visible from below. Tibiae cylindrical, not sulcate above.

By the remarkable structure of the scutellum and other characters closely allied to *Vitellus*, Stål, but the pronotal humeral angles are not produced in a spinous process, the sternal keel is much shorter, and the scutellar apical appendage is larger and differently shaped. As in *Vitellus* this appendage is not visible when the hemelytra are closed.

15. PETALASPIS TESCORUM, n. sp.

Straw-coloured, finely and rather thickly almost concolorously punctate, cicatrical areas and a longitudinal median line of pronotum, and scutellar apical appendage impunctate, an apical dot to clavus black, membrane (including veins) vitreous, centre of mesosternum (except the ridge) orange, apical margin of last dorsal segment and of last connexival segment above and beneath, and male internal genital appendages dark sanguineous. Second antennal joint not quite twice the length of first, third as long as second and somewhat shorter than fourth (fifth wanting). Sternal keel in the middle of its prosternal part very thin, translucent and almost vitreous. Sixth male ventral segment in the middle slightly longer than the two preceding segments together; first male genital segment short with subtruncate apical margin, second genital segment longitudinally bluntly ridged in the middle, on the sides with a transversely oval impression, apical margin sinuate but in the middle with a short narrow parallel process forming a continuation of the median ridge. Length, ♂ 9.5 mm.

Stevenson River.

16 ROEBOURNEA DIVERSA, Dist.

Tempe Downs, Macdonnell Ranges.

Distant placed this insect in *Basicryptus*, H. Sch., and Van Duzee, who gave a very good description of it under the specific name *tumidifrons*, placed it with a reservation in the genus *Phyllocephala* Lap. It belongs to a very distinct genus described by Schouteden under the above name. Van Duzee mentions only one fuscous vitta on either side of the venter, but normally there are two such vittae on each side. In the larvae, which have four-jointed antennae, the head and pronotum are constructed much as in the *imagines*, and they are also similarly coloured, but the pronotum has a very distinct black transverse median spot which is acutely indented laterally, and the abdomen has above and beneath a prominent black transverse spot at the middle of the lateral

borders of each segment; there is also a rounded black spot in the middle of the last four ventral segments, and the disk of the venter is remotely punctured with fuscous without the papillate sculpture of the *imago*.

To the many specimens collected at the above locality is appended a label to the effect that this species is "living at the base of the stalks and amongst 'Porcupine grass' (*Triodia pungens*)."

Fam. COREIDAE.

17. Mictis profana, Fabr.

Sullivan Creek.

18. Amorbus alternatus, Dall.

Palm Creek.

19. Aulacosternum punctipes, Stål.

Illara, James Range.

20. Leptocoris mitellatus, n. sp.

Red, pronotum rarely tinged with ochraceous, a large quadrate median spot on vertex more or less extended forwards over clypeus and juga, the pronotal calli, scutellum, a large transverse spot in anterior part of pleurae, two ventral patches, one on each side, extended from base of fourth to near middle of sixth segment and connected with each other along apical margin of fourth and fifth segments, antennae, rostrum, and legs black, hemelytra fuscous, clavus and corium more or less tinted with reddish and with a prominent obliquely transverse red spot occupying apex of endocorium and extended a little over interior basal angle of membrane, bucculae, acetabula, anterior margin of prosternum, spiracles, and (narrowly and more or less distinctly) posterior margin of pleurae and of ventral segments and lateral margins of abdomen whitish. Head with the juga slightly shorter than the clypeus and apically not raised above it, the low and blunt oblique anteocular elevations and the postocular calli with short and rather stiff black hairs, rostrum somewhat variable in length, reaching base of second or third ventral segment. Pronotum thickly but extremely finely subrugulosely punctulate, darkly pilose at the lateral margins and sparsely but more longly so on the collar which is but slightly convex, broader in the middle than at the sides, and not raised above the level of the calli, the disk with a median keel beginning between the calli and evanescent toward the middle or base, the lateral margins straight or slightly sinuate before middle, sub-

carinate, very narrowly if at all reflexed, scarcely indented at the ends of the transverse impression posteriorly terminating the collar. Scutellum indistinctly punctate. Hemelytra somewhat passing apex of abdomen, corium and clavus very finely alutaceous, scarcely punctate at all, clothed with a very short and fine decumbent pale sericeous pubescence, membrane dull. Pleurae impunctate, sericeously pubescent. Abdomen beneath with the dispersed puncturation almost imperceptible except in the two black patches where it is more distinct, middle of ventral disk rather longly palely pilose; second male genital segment with its median apical part almost vertically ascending, viewed from behind with a round impression on each side of the middle, the apical margin unisinuate, the apical angles conically produced straight backwards, the three appendages protruding from the interior of the segment pale testaceous, the middle one shorter than the others, narrowly triangular, acuminate at apex, the lateral ones with a small tubercle beneath at their base, viewed from below parallel from base to middle, where the outer margin is angularly bent, being oblique in its apical half; seen from the side the apical half of the lateral appendages is curved with the convexity upward. Length (excl. membrane), ♂ 10 mm., ♀ 10.5—11.8 mm.

Near Glen Helen, Macdonnell Range; Illamurta, James Range.

Belongs to the same group as *L. fimbriatus*, Dall. (the only Australian species hitherto known), but it is little more than half the size of that species, and the coloration both above and beneath is totally different, excepting the head which is similarly coloured.

21. Leptocoris vulgaris, n. sp.

Brick-red, pronotum (except calli and lateral margins), scutellum, clavus, corium, and in some specimens also middle of vertex slightly infuscated, a subapical fascia to prosternum, all acetabula, posterior part of pleurae, an apical laterally abbreviated mostly narrow fascia to the last three or four (rarely all) ventral segments, antennae, rostrum, and legs (excluding coxae) dark fuscous or blackish, membrane fuscous with an olivaceous tint, apical margin of prosternum and acetabula, and often also extreme posterior margin of pleurae whitish. Head with the oblique anteocular elevations rather narrow and well pronounced, juga slightly shorter than clypeus and apically not raised above it, rostrum variable in length, reaching base of second or apex of third ventral segment. Pronotum thickly and finely punctate, shortly palely pilose at the

lateral margins and on the collar which is distinctly convex and raised above the level of the calli, the disk with a median keel running from between the calli backwards and becoming very fine or evanescent toward the base, the lateral margins almost straight, narrowly depressed and a little reflexed, distinctly angularly indented at the ends of the transverse impression posteriorly terminating the collar. Scutellum scarcely punctate. Hemelytra passing apex of abdomen, corium and clavus thickly and very finely punctured, their sericeous pubescence rather indistinct owing to its extreme shortness, membrane dull. Pleurae very finely rugulose and thinly sericeous. Abdomen beneath almost impunctate, rather shortly and thinly pilose; second male genital segment with its median part obliquely ascending without impressions, apical margin bisinuate, apical angles subconically produced obliquely backwards, distinctly divergent, the three appendages protruding from the interior of the segment pale testaceous, the middle one shaped as in *L. mitellatus*, the lateral ones viewed from beneath parallel, viewed obliquely from below with a small tubercle near the outer margin beyond its middle, the space between the tubercle and the apex curved with the convexity upward. Length (excl. membrane), ♂ 8—9 mm., ♀ 9—10 mm.

Bagot's Creek; near Glen Helen, Macdonnell Range; near Dalhousie Springs. Illamurta, James Range.

Allied to the preceding species, but readily distinguished, apart from the smaller size and quite different colouring, by more distinctly punctured upper side, narrower and more raised anteocular ridges, more distinctly depressed and reflexed pronotal lateral margins with their distinct subapical indentation, more raised and convex pronotal collar, shorter and paler pilosity on the pronotal lateral margins and collar, less distinctly sericeous corium, shorter ventral pilosity, and differently constructed second male genital segment. It was apparently the commonest of the Heteroptera met with during the Horn expedition; very numerous specimens were collected, especially near Glen Helen.

Fam. MYODOCHIDAE.

22. Spilostethus pacificus, Boisd.

Ayer's Rock, on *Wahlenbergia gracilis*.

23. Spilostethus mactans, Stäl.

Dalhouse Springs.

24. Germalus sexlineatus, n. sp.

Dull, pale dingy ochraceous incuding antennae, rostrum, and legs, a dot on upper side of antenniferous tubercles, two dots (one on a level with the other) on upper side of first antennal joint, and one dot on under side of this joint black, a streak between the exterior upper dot of first antennal joint and the tip of the joint, a small spot near humeral angles of pronotum, apical angle of clavus and of corium, a spot at apical margin of connexival segments, and on the abdominal tergum three narrow vittae to the penultimate segment, a narrow fascia connecting the posterior ends of these vittae, and a broad median vitta to the last dorsal and the male genital segment fuscous, these abdominal markings tolerably well visible through the translucent membrane, a slightly oblique longitudinal line on each side of vertex and six percurrent narrow vittae on pronotum rusty red, three or four slightly infuscated sublateral spots to each ventral segment, femora sparsely dotted with black, except front side of fore femora. Head a little over two times broader than long and slightly broader than base of pronotum, impunctate, with an oblique impressed line between ocelli and base of ocular peduncle, this peduncle directed outwards and a little backwards, its anterior margin very short, less than one-third the width of an eye, whereas its posterior margin is much longer and almost but not quite touching latero-anterior margin of pronotum, eyes viewed from above slightly more than twice longer than broad, ocelli not quite twice more apart from each other than from the nearest point of the eyes, the distance between the ocelli being as long as between them and the posterior angle of the eyes, antennae a little longer than head and pronotum together, second joint twice the length of first, third one-third shorter than second, fourth subequal in length to third, bucculae slightly passing apex of antenniferous tubercles, rostrum reaching middle of intermediate coxae, first two joints subequal in length, third a little shorter than second and equal to fourth. Pronotum one-half broader than its median length, slightly narrowing from base to apex, sparsely and finely punctured with brown, a transverse postapical fascia not reaching lateral margins and the basal border impunctate, the two median reddish vittae nearer to each other than to the following pair, apical margin straight in the middle, obliquely truncate behind the ocular peduncle of the head, lateral margins almost straight. Scutellum as long as broad and one-third shorter than pronotum in the middle, finely and rather thickly punctured with fuscous, but with the usual

triradiate impunctate elevation. Breast finely and rather thickly punctate with blackish on the propleurae, with pale brownish on the meso- and metapleurae. Hemelytra (♂) reaching a little beyond apex of abdomen, corium with three percurrent rows of very small thick-set brown punctures, first row in its basal third running near the costal margin, then gradually somewhat deviating from it, second row placed in the middle, third near the claval suture and continued from its apex along apical margin of corium to apex of first row, clavus parallel in its basal third, then a little widening toward the commissure which is a little longer than half the length of the scutellum, with two rows of punctures similar to those of the corium, one along basal half of outer margin, the other along the commissure and continued a little way along the inner margin, basal part of clavus moreover with some extremely fine almost colourless punctures partly forming a row, corium and clavus for the rest impunctate. Abdomen impunctate, third, fourth, and fifth connexival segments partially exposed, extending a little beyond the costal margin of the closed hemelytra; male genital segment semicircular, beneath with a small round pit a little before apex. Length, ♂ 4.7 mm., incl. membrane, 5 mm.

Stevenson River.

Allied to *G. roseobistriatus*, Kirk. (by its describer wrongly referred to the genus *Geocoris*), but with the head broader as compared to the pronotum, different colouring of the head, scutellum, and abdomen, etc.

N.B.—Montandon has separated from *Germalus* a species from New Caledonia as belonging to a distinct genus, *Neogermalus*. The only difference is that in *Neogermalus* the ocular peduncle has the anterior margin shorter and the posterior margin more approaching or even contiguous to the latero-anterior margin of the pronotum, and that the eyes therefore are more oblique. The length and direction of the ocular peduncle are, however, very inconstant in the genus *Germalus*, and some of its described species certainly form distinct and gradual transitions from species with longer ocular peduncle directed a little forwards to such with shorter peduncle directed more or less backwards. In my opinion generic characters cannot, either in *Germalus* or in *Geocoris*, be taken from the shape and direction of the ocular peduncles. The more new species are detected, the more numerous the transitions become. The same is true of the size of the scutellum. It therefore seems to me that *Neogermalus* cannot be ranked as even subgenerically distinct from *Germalus*. Montandon holds *Ophthalmicus*

membraneus, Montr., as the type of *Neogermalus*, but I think there can be no doubt that the insect described by him under that name is quite distinct from Montrouzier's species. Montrouzier says in his description: "dessus du corps brun-foncé ou même noir," and the length of his species is 5.5 mm., whereas all species of *Germalus* are very pale in colour, and the length of the species described as *membraneus* by Montandon is 4.3—5 mm. There is nothing in Montrouzier's short description indicating that he had a *Germalus* before him, and his species belongs in all likelihood to the genus *Geocoris*. Being a *nomen false citatum*, Montandon's *membraneus* cannot according to the nomenclatural rules be maintained, and I propose for this species the name *Germalus montandoni*.—Under the specific name *dissidens* Montandon has described, as questionably belonging to *Germalus*, a species with black head, pronotum, and scutellum; but this species differs from *Germalus*, apart from the colour, by the structure of the metasternal orificia, which is always of great systematic importance and never variable to any great extent in the same genus. It clearly belongs to a distinct genus which may be briefly characterised thus:

Nesogermalus, n. gen.—Antenniferous tubercles on the outer side armed with a tooth. Metasternal orificia constructed as in *Geocoris*, subrotundate, callosely margined, not produced in a ridge. Other characters as in *Germalus*, Stål.—Type: *Germalus ? dissidens*, Mont.

25. Stenophyella sabulicola, n. sp.

Whitish testaceous, head with a black lateral spot behind the eyes, tergum of abdomen with two percurrent black vittae well visible through the pellucid hemelytra but in the dorsal genital segment resolved into small subconfluent black points, mesosternum in the middle with two pale brown vittae and between them with a narrow impressed percurrent median blackish vitta continued, though not impressed, through the metasternum; thickly and finely punctured, corium and clavus more coarsely and subseriately punctate, abdomen beneath extremely finely, almost imperceptibly punctulate, the puncturation concolorous with the following exceptions: a cluster of black points on outer side of antenniferous tubercles and in the middle of the two brownish mesosternal vittae, a longitudinal band composed of black points near anterior half of pronotal lateral margins and somewhat within lateral margins of venter from its base to apical margin of fifth segment. Head slightly shorter than pronotum in the middle, and with the eyes but slightly promi-

nent beyond pronotal apical angles, vertex three times broader than an eye, with an impressed longitudinal line on each side extended from near the ocelli to the level of anterior end of eyes, first two antennal joints on their outer side studded with very small black granules, rostrum reaching a little beyond front coxae, first joint not quite reaching anterior margin of eyes, second as long as first, reaching anterior margin of prosternum, third and fourth together slightly longer than second, of equal length, apical half of fourth joint black. Pronotum as broad as long and two-thirds broader at base than at apex, lateral margins straight, basal margin a little rounded between its lateral lobules. Scutellum equilaterally triangular, with a percurrent narrow smooth median ridge. Orificia short, curved, callosely margined, apically lobulately subprominent. Hemelytra reaching somewhat beyond base of female dorsal genital segment, inner half of mesocorium quite hyaline and impunctate, only with a row of punctures along the cubital vein, apical margin of corium straight with a small obtusangular sinuosity near apex of clavus and a very slight and short sinuosity a little before middle, clavus with a single row of punctures between the vein and the suture, which is shorter than apical margin of corium, claval commissure slightly shorter than scutellum, veins of membrane straight and simple. Abdomen in the female with the last dorsal segment rather deeply arcuately sinuate at apex, in the middle only half the length of the preceding segment, female dorsal genital segment more than twice the length of last dorsal segment, produced beyond the ventral genital segments, tapering toward the apex which is rather deeply but narrowly cleft, fifth ventral segment (♀) in the middle sinuate to the very base for reception of the sixth segment. (Last antennal joint and fore and hind legs wanting in the type). Length, ♀ 7.5 mm.

Stevenson River.

Differs from *S. macreta*, Horv. (the only other known species of the genus) by its larger size and by having the eyes narrower and less prominent, the rostrum (especially its second joint) shorter, the scutellum medially keeled, the mesocorium hyaline only in its inner half, the black punctures of the head and pronotum differently distributed, etc. If the specimen described by Horváth really be a male, the apex of the abdomen is bifid in both sexes of this genus.

26. Dieuches, n. sp.

Bagot's Creek.

A single mutilated specimen, unfit for description.

Fam. REDUVIIDAE.

27. Poecilobdallus formosus, Stål.

Bagot's Creek; Tempe Downs.

The colour of the upper side of the head is in some specimens as described by Stål, but usually it is black, excluding the part situated before the antennae, which is red with the clypeus blackish; the postocular part has above a yellow median line. The abdomen, which was lacking in the single type-specimen described nearly 60 years ago, is black with the broad, rather strongly rounded connexivum from its base to the middle of the sixth segment above and beneath, and a median ventral spot of very variable size red; this ventral spot sometimes small, placed at base of third segment, sometimes large, reaching from apex of second to near apex of fifth segment.

28. Havinthus longiceps, Stål.

Finke River near Bend; Dalhousie Springs. Idracowra. Illamurta.

This species is extremely variable in colouring and in the development of the granulation, and it is hardly possible to describe its varieties as they are connected by numerous transitional links.

29. Oncocephalus confusus, Reut.

Bagot's Creek.

Fam. VELIADAE.

30. Microvelia australica, n. sp.

Oblong, black with a cinereous bloom, a transverse apical spot to pronotum and the margin of its produced posterior part, connexivum (except extreme lateral margin and segmental sutures), lateral borders of venter, and an apical spot to last ventral segment luteous, a longitudinal line to pronotum velvet-black, acetabula and legs testaceous, the latter here and there infuscated. Head as long as broad, rostrum scarcely passing prosternum, dark testaceous, last joint piceous, antennae blackish, first two joints, except apices, dark testaceous, second joint as long as first, third a little longer than second, fourth the longest, slender. Pronotum rugulosely punctate behind the middle, lateral angles obtusely a little prominent. Hemelytra whitish, all veins and a vitta to the median discal area fuscous. Wings lacteous. Hind legs distinctly longer than middle legs; intermediate tibiae shorter than femora,

posterior tibiae as long as femora and trochanters together. Length, 2 mm.

Palm Creek.

This is the first *Microvelia* recorded from Australia.

Fam. NEPIDAE.

31. Laccotrephes tristis, Stål. Oefv. Vet. Ak. Foerh. XI., 241 (1854); Freg. Eugenies resa, Ins. III., 266 (1859); Ferrari, Ann. Hofmus. Wien III., 186 (1888).

Bagot's Creek; Alice Springs.

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ART. III.—*The Petrology of the Silurian Sediments near Melbourne.*

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(Communicated by Professor E. W. Skeats, D.Sc.)

1.—Introduction.

Silurian sediments form the base rocks of the city of Melbourne. Typical outcrops are exposed along the River Yarra from Princes' Bridge upwards, in Hawthorn and Kew, and also in the northern and western suburbs, Coburg and Moonee Ponds. Carefully selected specimens were taken from most of the outcrops. The rocks are remarkably uniform in megascopic and microscopic characters over the whole of Melbourne, so that the comparatively small collection of specimens may be taken as representative.

The rocks consist entirely of shales, mudstones and sandstones, thinly bedded. The beds average one or two feet in thickness. The shales and mudstones are loosely compacted but in certain cases are firm and tough where silicified. The sandstones contain much aluminous material. In some cases they are partially cemented into semi-quartzites by secondary silicification. In most cases the cement consists of fine clayey material, in which case the rock weathers down to a soft, porous, crumbly sandstone. The quartzite beds stand out in prominent relief from these. There has been an extensive replacement of the sandstones by limonite along the bedding planes.

These sediments are steeply folded and fractured around Melbourne. In general the strike is northerly, but owing to the complications of movements, such as sagging and pitching of the folds, and to the presence of numerous fractures, the strikes vary greatly from that of the main fold axes.

Some fairly large faults occur. In the bed of the Merri Creek at Coburg (see "Description of Sections," Rock No. I.) there occurs a well-developed fault breccia composed of angular fragments of sandstone, resembling the neighbouring Silurian sandstones, set in a matrix of the same material, and now almost entirely replaced by limonite. Small displacements are very widespread.

2.—Composition of the Sediments.

The sandstones, mudstones and shales are all highly aluminous. The principal allothigenic minerals identified microscopically are quartz, more or less fresh felspars, muscovite, and biotite. The accessories noted are tourmaline, iron oxides (magnetite or ilmenite), zircon, rutile, and perhaps anatase and sphene. Secondary or authigenic minerals present are sericite, limonite, leucoxene, quartz, and possibly pyrite, subsequently altered to limonite. Carbonates may occur to a small extent but no effervescence with acid was observed with the powdered rocks. Chlorite after biotite is present in some sections.

(*a*). *Essential Minerals.*—The detrital quartz ranges to about 0.5 mm. as a maximum in the sandstones. In some of the sandstones small well developed quartz veins have been formed by secondary solution and redeposition.

The quartz is angular in habit. It does not show any crystal boundaries. It frequently shows strain polarisation effects as the result of pressure. Inclusions of such minerals as apatite are sometimes found.

The felspar is found in two conditions. The greater amount occurs as turbid grey patches throughout the section of about the same size as the quartz, and in some cases in nearly as large an amount. These patches show, in some cases, remains of lamellar twinning. They consist essentially, as far as can be determined, of fine aggregates of secondary sericite. The original felspars have probably been altered by percolating solutions producing secondary mica. In some cases these sericitic patches have been subsequently stained by limonite impregnations.

A few unaltered grains of oligoclase occur in most of the sections. The refractive index, twin lamellation, and such extinction as can be observed refer it to oligoclase. These again are of the same order of magnitude as the quartz.

No felspar has been identified in the mudstones and shales, though possibly originally present.

Mica occurs in three forms:—1, As long ragged clear crystals of muscovite sometimes nipped in between the neighbouring sand grains. These are clearly detrital and average about one millimetre in length. 2, As secondary sericite after felspar, and also throughout the groundmass constituting most of the clayey matter of the groundmass. This may be partly allothigenic and partly authigenic as is certainly the case with that representing felspar remains.

The above minerals are characteristic of every sandstone examined.

3, As biotite. This occurs in several of the sandstones. It is generally pleochroic from a pale greenish yellow to a darker tint. In some sections it is nearly as plentiful as the muscovite. It has the same relative size. The colour may be partly due to iron-staining. In some cases it has been altered to chlorite.

(*b*). *Accessory Minerals.*—Tourmaline is the chief accessory. It is to be found in every sandstone sectioned. It was not identified in the shales or mudstones. It occurs as rounded detrital grains showing marked pleochroism from greenish-brown to colourless. It sometimes shows good crystal boundaries.

Zircon occurs in most of the sections. It is generally in more or less rounded grains showing the remains of crystal faces. It is always clear and colourless.

Rutile occurs in rounded detrital grains. These are mostly dark reddish brown, but in one case a dark grey grain was identified.

Black Iron ores occur throughout the rocks in irregular grains, either as magnetite or ilmenite.

A certain amount of carbonaceous material may occur in some of the rocks, but cannot be differentiated from the iron oxides.

Anatase and sphene possibly occur, but their identification was not definite, owing to the very small size of the grains.

(*c*). *Secondary Minerals.*—Limonite is the chief secondary mineral. It replaces quartz and mica and probably also felspars. It is responsible for the general colour of the sandstones. It is not so prominent in the shales. Pale-green chlorite occurs as an alteration product of the biotite. Secondary quartz veins are present in some of the sandstones. Secondary rutile occurs as fine needles in sericitic matter, possibly after biotite.

Separation of Minerals with Heavy Liquid.

A heavy liquid separation was undertaken to isolate other minerals which might be represented in small quantity. A promising sandstone No. 13 (see "Description of Sections") from Studley Park was crushed in a mortar and passed through a 120 mesh sieve and then the fine muddy material was panned off with water. This method of separating the fine material saved any small particles of heavy minerals which might be present, but got rid of the fine quartz and micas.

The washed product was then divided into two portions by an electromagnet. The demagnetised product was then again separated into two portions, a heavier and a lighter by means of flotation in

acetylene tetrabromide S.G. 2.938, following the general method described by T. Crook, A.R.C.Sc. (Dublin), F.G.S., in Hatch's "Petrology of the Sedimentary Rocks."

The heavy portion was then examined under the microscope in media of different refractive indices. The following minerals were thus recognised :—Tourmaline, zircon, rutile, magnetite, sapphire, topaz, a little biotite and chlorite, some quartz, probably attached to some of the other minerals during flotation, and perhaps kyanite.

The tourmaline is abundant, and in many cases shows good crystal boundaries. It contains many microscopic inclusions of other minerals, and of gas bubbles. It is generally yellow brown to dark brown, but some fragments polarise from a blue green to a pure green.

Zircon comes next in abundance. The crystals show almost perfect crystal faces and are in many cases zoned. Faces shown include prisms and pyramids.

Rutile occurs as dark brown prisms generally, with pinacoidal terminations.

Magnetite was also noticed in the demagnetised (?) product. It shows characteristic rectangular outlines. It was probably too small in this case to separate itself efficiently from the sand under magnetic influence.

Sapphire occurs as deep blue, slightly pleochroic, irregular, angular grains, showing low polarisation colours, and is fairly plentiful.

Topaz occurs as rounded and irregular grains, and in many cases has many inclusions, some dark, which are probably iron ores.

A little biotite altering to chlorite was found. In one case the chlorite showed a fine spherulitic structure.

A doubtful crystal of kyanite was recognised, but as only one grain was found it is not considered wise to positively assert its presence.

3.—Description of Rock Sections.

Note.—The rock sections are included in the collection of the Geological Department of the University.

(*a*). *Coburg Specimens.*—Rock No. 1 consists of a hard breccia composed of angular sandstone fragments set in a matrix of finer material largely replaced by iron oxides.

Microscopically the rock fragments show quartz, muscovite, and tourmaline set in a groundmass of quartz and secondary mica. The rock is clearly a fault breccia. It is to be found about 100 yards

east of the Newlands Street West bridge over the Merri Creek in the creek bed.

No. 2 is a typical micaceous sandstone. It is a yellowish loosely compacted rock showing quartz grains and flakes of muscovite. Microscopically it shows quartz, muscovite and tourmaline. This specimen was obtained from the road section just west of the cemetery in Elizabeth Street.

No. 4a is a light yellow mudstone. Microscopically all that can be recognised are minute fragments of quartz and muscovite set in a micaceous clayey groundmass. Spots of reddish-brown mineral with cubical outlines are possibly limonite after pyrite. It was obtained just to the west of the Newlands Street West bridge over the Merri Creek.

(*b*). *Moonee Ponds Creek Specimens.*—No. 3 is a dark, fine-grained sandstone, splitting well along the bedding planes. The split faces are covered with small flakes of muscovite. The rock shows dark bands. Microscopically the section shows quartz, muscovite, biotite, altered plagioclase, oligoclase (fresh), zircon, tourmaline, rutile, and ilmenite or magnetite, and dark bands of carbonaceous material. Some of the quartz grains contain inclusions of apatite. The tourmaline shows good crystal faces in some cases. Secondary minerals present are sericite, chlorite after biotite, a little carbonate, and limonite. The specimen was obtained from a cliff section on the creek about 100 yards north of the Brunswick Road bridge.

(*c*). *Hawthorn Specimens.*—No. 5 was obtained from a small point on the left bank of the River Yarra, just below the bend up stream from the Glen Tea Gardens. It is a dense grey sandstone, showing quartz and muscovite. Deposition of limonite has taken place along joint planes.

The section shows quartz, muscovite, tourmaline, zircon, fresh oligoclase and altered plagioclase, magnetite or ilmenite, leucoxene and green biotite, also possibly sphene. Some carbonaceous matter is present. Secondary limonite and sericite and clayey interstitial matter are also present.

(*d*). *Kew Specimens.*—i., Victoria Street Bridge Section—Rock No. 17 from the north side of Victoria Street at the top of the hill above the bridge is a fine grey sandstone traversed by veins of limonite and secondary quartz. Microscopically the section shows quartz, muscovite, tourmaline, zircon, and carbonaceous material, set in a fine groundmass of quartz and sericite. Sericite after felspar is common. The secondary quartz veins are probably later

than the limonite impregnations, as they cut through them in places. The quartz veins crossing small cracks may have offered an obstruction to subsequent iron-bearing solutions.

No. 19 is a light-grey micaceous sandstone showing quartz, muscovite, tourmaline, zircon, biotite, and oligoclase in a fine groundmass of quartz and sericite. Secondary minerals present are limonite, sericite, and chlorite. This rock was obtained about two chains below No. 17 on the north side of the cutting.

No. 20 is a yellowish loosely compacted micaceous sandstone similar to No. 2 from Coburg. It was obtained about half a chain below No. 19. It shows quartz, muscovite, tourmaline, oligoclase, altered plagioclase, biotite, zircon, rutile, chalcedony fragments, and possibly anatase. Secondary minerals are limonite, leucoxene after ilmenite, sericite, and chlorite.

No. 22 is a hard, porous, greyish-white quartzite, showing flakes of muscovite. Microscopically it shows quartz, muscovite, tourmaline, altered plagioclase, magnetite or ilmenite, zircon, leucoxene after ilmenite, and rutile in a groundmass of fine quartz and sericite. Secondary rutile occurs in very fine needles in cloudy sericitic patches, possibly altered biotite. It was obtained from a prominent bed six chains from No. 17 on the same side.

ii., Studley Park Specimens.—No. 6 is a hard, compact sandstone traversed by secondary quartz and limonite veins. The section shows quartz—some with apatite inclusions—a very little muscovite, zircon, rutile, tourmaline, magnetite or ilmenite, sphene, and secondary sericite and limonite. The location of all Studley Park specimens is shown on the sketch map (see below).

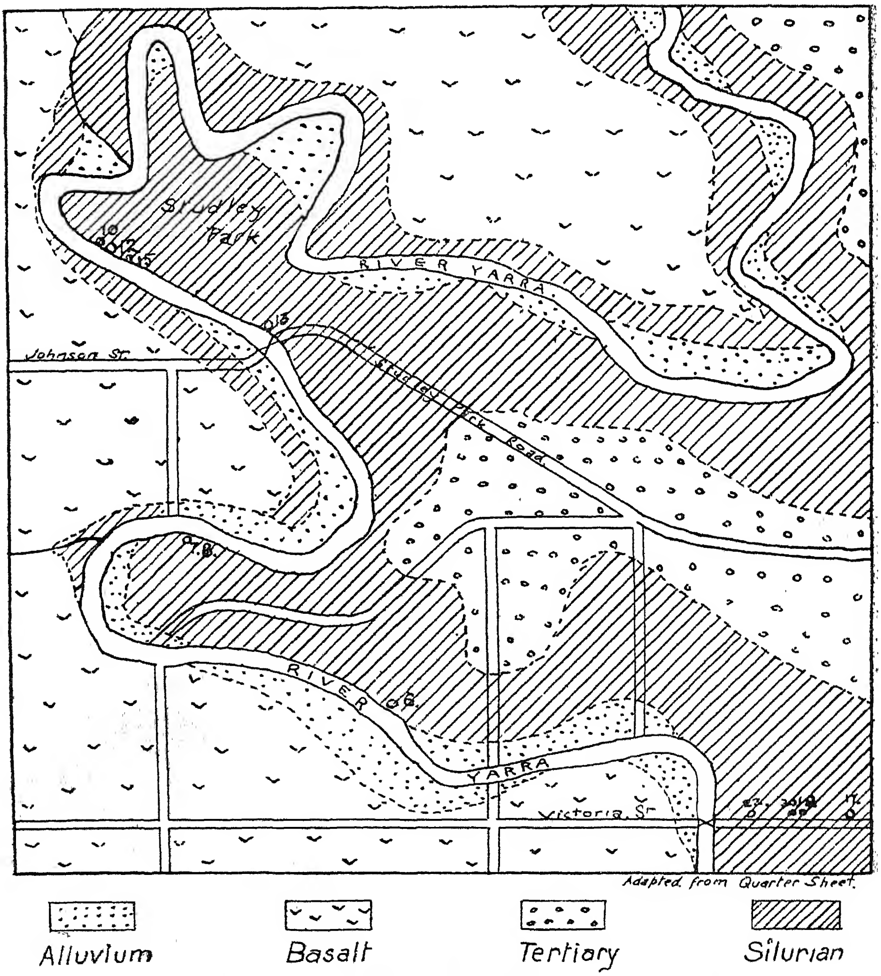
No. 8 is a micaceous mudstone with grey and yellowish bands. Microscopically it shows distinct current bedding. Minerals identified in the section include quartz, muscovite, and tourmaline, with secondary sericite and limonite. Some of the limonite is probably secondary after pyrite judging by its crystal outline.

No. 10 is a white mudstone from the crest of an anticline on the river path, about a quarter of a mile N.W. of Johnston Street Bridge. Microscopically it shows quartz, muscovite, biotite, chlorite, sericite, and limonite. It is fairly even grained, with a few larger fragments of quartz here and there.

No. 12 is a yellowish, hard, dense quartzite with secondary quartz and limonite veins. Microscopically it shows quartz, muscovite, oligoclase, altered plagioclase, tourmaline—brown and grey—zircon, cherty and sericitic intersticial matter, chlorite and limonite.

No. 13 is the rock selected for separation by heavy liquid. Microscopically the following minerals were identified :—Quartz, muscovite, tourmaline, oligoclase, altered plagioclase, magnetite, zircon, rutile, biotite, and secondary sericite and limonite.

No. 15 is a banded grey and yellow shale showing muscovite along the bedding planes. Under the microscope the section shows quartz,



GEOLOGICAL MAP of KEW

0 ½ 1 mile.

muscovite, and carbonaceous material in a clayey groundmass. It is very even grained.

(*e*). *South Yarra Specimen*.—No. 9 was obtained from the cliff section on the left bank of the River Yarra just below the Church Street Bridge. It is a hard, tough, cherty looking rock. Under the microscope it shows small angular fragments of quartz, and a little muscovite, tourmaline, and rutile, in a very fine sericitic groundmass. It seems to have suffered considerable pressure. Secondary limonite is also present throughout the rock.

4.—Metamorphism.

Practically no metamorphism of the rocks has occurred. Although intensely folded and fractured no cleavage is developed. No contact metamorphism has taken place.

The series is intruded by two series of dykes, one basaltic and the other of the nature of quartz porphyry. The only alteration is that due to the percolation of solutions containing iron derived from the dykes. The sediments are largely impregnated with limonite at the contacts.

5.—Deposition of the Sediments.

Chapman[1] refers the Melbournian sediments to a warm shallow sea on the evidence of the prevalence of the brachiopod Lingula, and the almost complete absence of the corals. This view is supported by the writer. The general fineness in grain suggests that the sediments were deposited some distance from the shore. Conglomerates occurring at Keilor, about 10 miles from Melbourne, probably represent the nearest part of the shore line sediments of the Silurian sea.

The admixture of relatively coarse sand with the fine materials of the shales suggests that the sediments may have been laid down under flood conditions or under rapid variations in the strength of the currents. This view is supported by the relative thinness of the beds and the rapid alternation of sandstone and shale.

6.—Origin of the Constituent Minerals.

Two sources are possible for the material of the sediments :—

i. They may have been derived from a pre-Silurian igneous rock; or, ii., They may have been derived from a pre-Silurian sediment. Both sources are also possible.

1. "On the Palaeontology of the Silurian of Victoria." Proceedings of Section C, p. 213, Australasian Association for the Advancement of Science, Melbourne, 1913.

Jutson[1] believed that the Silurian sediments at Warrandyte were derived solely from a sedimentary series because no pebbles of igneous rock were found by him in the Warrandyte conglomerate.

Junner,[2] in his paper on the Diamond Creek area, concludes that the sandstones of that district were derived to a "fair extent" from pre-Silurian igneous rocks. He gives the following reasons for his view :—

1. The abundance of muscovite.
2. The presence of biotite, plagioclase, and chlorite, which is usually derived from unstable iron magnesium minerals.
3. The occurrence of zircon and rutile crystals in the quartz grains in the sandstones may indicate an igneous origin for such quartz.
4. The constant presence of tourmaline suggests such an origin.
5. The absence of metamorphic minerals, etc., shows that they were not derived from metamorphic rocks.

The last does not show, however, whether the Silurian sediments were derived from igneous or sedimentary rocks. Muscovite and tourmaline, whilst suggesting an originally igneous origin, are stable minerals and may easily be handed down from one sediment to another. Similarly, quartz grains containing zircon and rutile may easily have suffered more than one transportation before coming to their final resting place.

The presence of biotite, plagioclase and chlorite suggests that the rocks were derived to some extent direct from pre-Silurian igneous rocks, especially if the felspar were fairly fresh.

The writer finds felspar to be present in two conditions in his sections; the one much decomposed but showing traces of twin lamellation, and the other quite clear and fresh. The natural inference from this fact is that the decomposed material has suffered more handling than the fresh. This would suggest that the clear material has been directly derived from an igneous source, possibly granitic, whilst the decomposed material has been derived from an older sediment. No pre-Silurian granites, however, are known near Melbourne with certainty. The You-Yangs granite may be pre-Silurian.

The writer inclines to the view that both origins are probable for the rocks of the Melbourne district. This view is strongly supported

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1. "The Structure and General Geology of the Warrandyte Gold-field, &c." Proc. Roy. Soc. Victoria, vol. xxii., pt. II., 1911.
2. "General and Mining Geology of the Diamond Creek Area." Proc. Roy. Soc. Victoria, vol. xxv., pt. II., 1913.

by the fact that the plagioclase occurs in two conditions. The presence of biotite and chlorite supports the view of an igneous origin for part of the sediments.

The strain polarisation of some of the quartz may have been produced, not in situ but in an older sediment. Our known Ordovician rocks have suffered much greater stresses than the Silurian. All the quartz does not show strain polarisation.

The Ordovician sediments of Victoria have not yet received any attention petrologically. When they are examined they will probably show the presence of much similar material to that of the Silurian. An Ordovician quartzite section in the writer's possession shows zircon and tourmaline.

In conclusion the writer wishes to gratefully acknowledge the invaluable help and guidance of Professor Skeats through all stages of the work, and to Dr. Summers for various suggestions.

[PROC. ROY. SOC. VICTORIA, 29 (N.S)., PT. I., 1916].

ART. IV.—*The Paleontological Sequence of the Lower Ordovician Rocks in the Castlemaine District.*

PART I.

BY W. J. HARRIS, B.A.

(With Plate I.).

[Read 11th May, 1916].

Victorian economic geology, more particularly in so far as it is concerned with the origin and occurrence of auriferous lodes, is so intimately associated with the folding of palaeozoic strata and the resulting problems, that any reliable guide to the order of superposition of the various beds is likely to be useful. The absence of conglomerates and other well defined bands deprives geologists of benchmarks that would be of assistance in working out the folding of the rocks in localities where good exposures are wanting. Recognition of the part certain favourable beds play in the enrichment of lodes, more particularly at Ballarat, and to a lesser extent at Bendigo, Daylesford, and elsewhere, has accentuated the importance of obtaining a working knowledge of the stratigraphical relations of the rocks of these localities. In the absence of this knowledge even expert opinion is liable to err. Mr. E. J. Dunn states that "the South Eureka rocks appear to be well up in the Castlemaine zone . . . Spring Gully appears to be still higher. . . . The Fryerstown belt is in the Castlemaine zone."[1] These three localities seem on palaeontological evidence to be all Upper Bendigonian, and hence much more favourable for quartz mining than the above makes them appear. The researches of Dr. T. S. Hall and others have resulted in the subdivision of the Victorian Lower Ordovician rocks into four series—Lancefield, Bendigo, Castlemaine and Darriwil, in ascending order. The relations between the three lower series are clearly shown in several areas, and are generally known, but, though the Darriwil series is recognised as somewhat above the Castlemaine series, its exact stratigraphical position has remained in doubt. This paper includes, among other efforts, an attempt to co-ordinate the Castlemaine and Darriwil series.

1 Dunn, E. J., Rec. vol. iii., part ii., Geol. Surv. Victoria.

I. Area.

The area over which these observations extend includes about 100 square miles. Its approximate boundaries are, on the north and east the granite massif of Mount Alexander, on the west the Muckleford Creek, and on the south a line drawn from Strangways through Tarilta, Glenluce, and Fryerstown to the Elphinstone Tunnel on the Melbourne to Echuca railway.

II. Previous Workers.

A. R. C. Selwyn[1] as early as 1853 made a section of the beds from the Campaspe to the Loddon along a line passing through Mounts Alexander and Tarrengower.

The late Dr. T. S. Hall[2] in a paper to this Society on the Geology of Castlemaine (1894) shows that the differences between the graptolites of the various outcrops are due to the stratigraphical relation of the beds. From the palaeontological evidence he was able to demonstrate their succession and outline six zones. He also gives a general account of the geology of the district. His paper deals particularly with the area to the south and the east of the town of Castlemaine and forms the basis for all later palaeontological work on this area. The general lines of the classification of the graptolite zones indicated in this paper have since been independently confirmed in other districts. The writer during the years 1912-1915 examined all but three or four of the outcrops previously visited by Dr. Hall, and is able to attest the accuracy of the deceased worker's observations. One who has traversed the rough hills around Castlemaine can thoroughly appreciate the painstaking and accurate work which, without the aid of present-day facilities for travelling, Dr. Hall carried out over twenty years ago. The difficulties in the way have resulted in a scientifically fertile field lying idle for more than two decades.

Mr. W. Baragwanath[3] deals with portion of the area in Memoir 2 of the Geological Survey of Victoria. Axial lines are plotted and a section given showing the succession of the strata. The section is evidently based mainly on observed dip. No particular section line is marked on the map, but the section appears to be along a line from Forest Creek through Quartz Hill to Gaol Hill. If so, it errs in not showing a ge-anticline on the Cemetery Reef where the lowest

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1 Geology and Mineralogy of the Mt. Alexander Goldfield, Parl. Papers, 1853-4, vol. ii., et Q.J.G.S., vol. x.

2 Proc. Roy. Soc. Victoria, vol. vii. (n.s.), 1894.

3 Castlemaine-Chewton Goldfield. Mem. 2 Geol. Surv. Vic.

beds north of Forest Creek occur. These beds are on the Wattle Gully horizon, and *Didymograptus bifidus* is found at more than one place along the line. The beds to the east are only Middle Castlemainian, while, further east still, on the east side of Forest Creek, Upper Castlemaine graptolites are found.

Mr. H. Herman,[1] in a brief description of the lodes of Castlemaine, gives a section, apparently based on the one just mentioned, and marks on it three zones—viz., Bendigo, Wattle Gully, and Castlemaine. The above criticism applies to this section also. From a palaeontological standpoint both are in error in showing the central beds too high in the series.

Besides these papers there are others dealing incidentally with the district. These, and also Dr. Hall's other papers on graptolites, will be referred to when necessary.

III. Characteristics of Fossiliferous Rocks.

Graptolites are widely distributed throughout the district and have been found at more than one hundred localities. They occur in slates of every colour. The slates of the *Oncograptus* zone often bear a distinct resemblance in colour and texture to certain Upper Ordovician rocks, particularly those exposed along the Saltwater River near Digger's Rest, but in the state of our knowledge no importance should be attached to lithological resemblance. With isolated exceptions graptolites in this district are found only in slates or fine mudstones which as a rule are less common than sandstones. Limestone of Ordovician age is absent. Quartz grit ridges and bands of coarse sandstone occur, but, though it may be possible to do so, no attempt has so far been made to correlate them. One is therefore compelled to rely entirely on the fine sediments, often so cleaved that the fossils are difficult to break out. This will be the more readily understood when it is realised that the cleavage is rarely parallel to the lamination and often crosses it at an angle of 30° or more. It is therefore difficult or impossible to obtain a good idea of the facies of some outcrops, though if the beds are Upper Castlemaine *Didymograptus caduceus* may often be recognised along the broken edge of a slab.

IV. Limitations of Mathematical Stratigraphy.

It is almost unnecessary to say that no method of working out the problems of rock folding in an area is more accurate than measure-

1 Economic Geology and Mineral Resources of Victoria. Bull. 34, p. 24, Geol. Surv. Vic.

ment and plotting by strike, dip, and pitch, and if it were always possible to employ this method, palaeontology, as it is used here, would lose much of its value. Anyone who has worked over a considerable area of country where exposed sections are few, knows how really limited, under such circumstances, the mathematical method is, and, where sections do occur, how interdependent the mathematical factors are. In the constantly varying angle of dip according to the portion of an anticline or syncline exposed at the surface, anything like accuracy is impossible and with the long low curves of pitch one is at a complete loss. Added to these difficulties, there is at Castlemaine the problem of overturned beds which occur in the east of the area and render valueless observations of dip obtained in shallow cuttings. These are often vitiated also by surface drag or warp diagonal to the directions of dip and strike, which gives a false dip.

V. Stratigraphical Value of Graptolites.

In the slates of Castlemaine there is sufficient evidence to be obtained of the life history of many species of graptolites to afford a fairly complete set of zonal fossils. The evidence is cumulative and not isolated, and that of the many species that together make up a facies is rarely at fault. From a zonal standpoint Dr. Hall[1] has used the Dichograptidae—*Tetragraptus approximatus* (Nich.), *T. fruticosus* (J. Hall), and *Didymograptus bifidus* (J. Hall)—with conspicuous success in his classification of the Lower Ordovician rocks of Victoria. Miss Elles[2], regarding the rise and fall of a genus and species, observes that " a certain resemblance of thecal characteristics, number of thecæ in a given space, inclination of ventral and apertural margins to the axis of the stipe, and the amount of thecal overlap may be regarded as (a) of genetic origin and therefore (b) of systematic importance; and further, that a natural group with relatively few stipes was evidently developed from multiramous forms, so that of the usually accepted classification the Dichograptidae are highly important chronologically." There seems no doubt that the gradual progression from multiramous to simpler forms is world wide. At Castlemaine *Clonograptus* is common in the lower beds, and *Tetragraptus* and *Goniograptus* are more common in the lower than in the higher beds. *Diplograptus* occurs infrequently in the middle beds, but becomes more com-

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1 Recent advances of our knowledge of Victorian Graptolites and elsewhere.

2 Graptolite Fauna of the Skiddaw Slates. Q.J.G.S., vol. 54 (1898), p. 529 ff.

mon later, while *Trigonograptus*, *Oncograptus*, *Lasiograptus*, and *Glossograptus* appear still later. The Upper Ordovician and Silurian graptolites are quite distinctive. Only the broadest outline seems possible at present, and conclusions drawn from observations on one side of the world may not be applicable to conditions on the other. For example, Elles, Wood and Ruedemann[1] all agree in deriving *Dichograptus octobrachiatus* from *Loganograptus logani*. In Victoria, as Dr. Hall[2] has pointed out, the order of occurrence is reversed, for while *D. octobrachiatus* is found in Upper Bendigo beds, *Loganograptus* is Upper Castlemainian. Differences such as this in the distribution of genera make one hesitate to generalise.

VI. Dr. Hall's Classification of Castlemaine Graptolites.

The following classification is that given in Dr. Hall's paper on the Geology of Castlemaine.[3] The zones are arranged in descending order as there set out.

1. Zone of *Loganograptus logani*.
2. Zone of *Didymograptus caduceus*. (Victoria Gully Beds.)
3. *Phyllograpto-caduceus* zone.
4. Burns' Reef beds. (*Phyllograptus typus*, with no predominant associates.)
5. Zone of *Didymograptus bifidus*. (Wattle Gully Beds.)
6. Zone of *Tetragraptus fruticosus*.

The facies of each zone is not given in detail, though it is briefly discussed. In another place Dr. Hall[4] states that "*Phyllograptus typus* long persists and is survived a short time by *P. angustifolius*. Specimens of *Diplograptus* appear in the higher beds but not apparently in the lower. A species of *Clonograptus* occurs in the lower beds, but soon disappears. *Loganograptus logani* puts in an appearance in the highest zones, and ranges into the Darriwil series."

VII. Proposed Revised Classification.

The table recorded below[5] shows the classification proposed. The beds are arranged in descending order and Dr. Hall's numbering is retained to render comparison easier. Beds above the Castlemaine series are prefixed with the letter "A."

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1 Graptolites of New York, I. N.Y. Mus. Mem. 7 (1894), table op. p. 554.
2 Graptolite-bearing Rocks of Victoria. Geol. Mag. (n.s.), Dec. iv., vol. vi. (1899), pp. 442-443.
3 Geol. of Castlemaine. Proc. Roy. Soc. Victoria, vol. vii. (n.s.), 1894, p. 88.
4 Graptolite-bearing Rocks, op. cit., p. 443.
5 Vide p. 55.

GRAPTOLITE ZONES OF THE CASTLEMAINE DISTRICT.

Series and Division.	No. of bed on map.	Locality of Typical Development—Castlemaine.	Zonal Fossils.	Other Characteristic Fossils.
Darriwil (W. J. Harris and T. S. Hall)—				
Upper (or Darriwil of Dr. T. S. Hall)	A	Guildford-Strangways Road	Glossograptus, sp. indet. Trigonograptus Lasiograptus (absence of C. morsus)	Diplograptus, cf. angustifolius. " gnomonicus, sp. nov. Didymograptus caduceus. " v-deflexus, sp. nov.
Middle	A	Guildford-Strangways Railway	C. morsus Trigonograptus (absence of Oncograptus)	Diplograptus gnomonicus, sp. nov. Didymograptus caduceus. " v-deflexus, sp. nov. Phyllograptus, sp.
	A	Chinamen's Creek	Cardiograptus morsus Oncograptus Trigonograptus	Diplograptus gnomonicus. Didymograptus caduceus. " v-deflexus, sp. nov. Phyllograptus, sp.
Lower	A	Woodbrook Road	Oncograptus upsilon Trigonograptus (absence of C. morsus)	Didymograptus caduceus. " v-deflexus. Phyllograptus, sp. Didymograptus caduceus, var. manubriatus
Castlemaine—				
Upper	1	McKenzie's Hill	D. caduceus (max. develop.) Loganograptus logani	Didymograptus, spp. Diplograptus, spp.

GRAPTOLITE ZONES OF THE CASTLEMAINE DISTRICT (*Continued*).

Series and Division.	No. of bed on map.	Locality of Typical Development—Castlemaine.	Zonal Fossils.	Other Characteristic Fossils.
Castlemaine— Upper (*cont.*)	2	Victoria Gully	D. caduceus (absence of P. typus)	Dichograptus, cf. octonarius. Diplograptus, spp.
Middle	3	Victoria Gully East	D. caduceus (small) P. typus	Dichograptus, cf. octonarius. Clonograptus, sp.
	4	Burns Reef	P. typus (absence of D. bifidus)	As in bed 3
Lower	5	Wattle Gully	D. bifidus (absence of T. fruticosus)	P. typus. P., cf. angustifolius. D. octobrachiatus Clonograptus, spp. G. crinitus. T. pendens. T. similis.
Bendigo— Upper	6	Daphne Reef	T. fruticosus (3-branched)	As in Wattle Gully Beds, and G. macer. G. thureaui.
Middle	7	South Fryerstown Race	T. fruticosus (4-branched)	G. macer. T. pendens T. similis. P. cf. typus. Didymograptus latus.

Only forms of fairly certain identity are given in this table; more extended search will probably extend the range of some of the species. The horizontal Didymograpti present difficulties which minimise their suitability for use as zonal fossils, though it is probable that detailed work with them will lead to instructive results. Other forms such as *T. serra* and *T. quadribrachiatus* appear to range through all zones. *T. serra* is very common in some of the beds of the Darriwil series as constituted in this paper, *Goniograptus* is represented in the Middle Castlemaine beds by one specimen of a new species and only one specimen of *D. octobrachiatus* has been found in Victoria Gully beds. Only three specimens of *Triaenograptus*, T. S. Hall, are known, and only two of these were found in situ. The futility of using such species in an account of zonal distribution is obvious, and, with a view to simplicity, it has been thought better to give only the more useful species.

VIII. Classifications Compared.

It is apparent that this scheme of classification supplements the older one. The following notes on the two classifications will serve to show resemblances and differences:—

1. Beds of the Darriwil series, as previously constituted, have for the first time been recorded from the Castlemaine district.

2. The meaning of the term Darriwil has been extended so that in the Darriwil series are now included not only those beds referred to the Darriwil by Dr. Hall, but also previously unrecognised beds between these and the Upper Castlemaine (*Logano-caduceus*) zone. I at first constituted these beds a new series under the name "Yapeen," but I found later that apparently all these beds did exist in the Darriwil district, and it seemed advisable to retain that name for the series, thus giving it an extended meaning. This alteration involved many alterations in the text, but was made too late to enable the whole paper to be recast.

3. The Castlemaine series remains as described by Dr. Hall. The two zones of the Middle Castlemainian are not always distinguishable, and it was at first thought better to unite them. However, as Dr. Hall[1] after mature consideration separated them (they appear as one zone in an earlier paper), it was decided to make no change. The test for distinguishing them, "the comparative rareness of *D. caduceus*"[2] in the lower bed, is weak and not always applicable.

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1 Geol. Castlemaine, op. cit.

2 Geol. Castlemaine, p. 70.

4. Bendigo beds lower than any described in the earlier paper have been recorded South of Fryerstown. In them occur *T. fruticosus* (4-branched form), and *D. latus* (T. S. Hall). Dr. Hall mentions the latter species as probably indicating Lower Bendigonian. This discovery has involved the division of the *T. fruticosus* zone into two—one characterised by the three-branched form, and the other by the four-branched. The question arises as to what differences should be tolerated in any one zone, for between the typical beds of these zones (placed with the lower zone in this paper), are beds containing three and four-branched forms. At Tarilta, Bendigo, and at one outcrop on the Fryers-Chewton Road, the three-branched form is found with *D. bifidus*, the zonal fossil of the succeeding zone. The same merging of zone into zone is present throughout all the series, and shows that any division of palaeontological development into stages must not be too arbitrary. While, therefore, a number of zones can be distinguished, yet between all of them are transitional beds which serve to link them. This will be again referred to in this paper.

IX. Stratigraphical Relations and Typical Sections.

To obtain a definite idea of the gradual change of facies at the various outcrops it is necessary to work across the area from east to west. If it were possible to travel in a straight line west from the Elphinstone Tunnel this would involve a walk of ten miles. An equally or even more instructive section could be made by starting south of Fryerstown and going east to Limestone Creek—a distance of some seven miles; but exposures along this line are less common. In either case the presence of gullies and the concealment of the bed rock by recent alluvium make it necessary to zig-zag and to piece together evidence obtained from north and south of the direct line. The pitch of the numerous small anticlines and synclines being unknown it is impossible to say what the dip will be north or south of any observed outcrop, the whole country having, as Dr. Hall[1] has pointed out, a resemblance to a troubled sea, wave succeeding wave in every direction. The surface "drag" of rocks on the east or west slopes of hills make surface indications of dip almost valueless. To add to the difficulty a dip may change from easterly to westerly without a syncline or an anticline having been observed. The sections included in this paper have therefore been made diagrammatic. This was the more necessary since west of Castlemaine comparatively few observations of dip can be made.

1 Geol. Castlemaine, p. 65.

(*a*) *The Elphinstone Tunnel—Castlemaine Section.*

This section for the first five miles is based mainly on the evidence of the cuttings on the Melbourne-Echuca Railway from the Elphinstone Tunnel (72 miles) to the 77-mile post south of the town of Castlemaine. The section for the next two miles is based on observations made on the hills south and south-west of Castlemaine. West of this in a direct line evidence is scanty. The graptolites of the railway cuttings have been described by Dr. Hall[1]. With the record of his observations I have rarely found it necessary to disagree, but, thanks to greater facilities for travelling, the opportunity has presented itself of filling in more detail. The rocks at the western entrance to the tunnel dip west owing to inversion. *Tetragraptus fruticosus* is to be found in a small drainage channel south of the railway, indicating the Upper Bendigonian horizon. The fine anticline mentioned by Dr. Hall[2] is now obscured by surface soil, but calculating its position, I paced west, and was fortunate in locating the "repeat" outcrop of *T. fruticosus* near the 72-mile post. The calculation was afterwards found to have been unnecessary as the anticline is clearly shown on the side of the road to the north of the line. The next observed graptolite beds occur in the second cutting. Here two bands of fossiliferous slate occur, and an anticline causes both to be repeated; while still another band occurs further west. All are Wattle Gully (*D. bifidus*) beds—Lower Castlemainian.

The next outcrop, a few chains east of the 73-mile post (all mile posts mentioned are those on the railway), has *Phyllograptus typus* associated with the small form of *Didymograptus caduceus*. *D. bifidus* is not found. The horizon is Middle Castlemainian. Just past the 73-mile post the large form of *D. caduceus* occurs, and since it again occurs along the line of strike less than half a mile to the south and is there associated with *Diplograptus* sp. and *Loganograptus logani*, I have felt justified in indicating this as Upper Castlemaine. Three chains further west of the mile post the same zone repeats, and about three hundred yards still further west *Oncograptus upsilon* may be found in light-coloured slates with a westerly dip, and a little further on *Trigonograptus*. These beds are best developed at the 73½-mile railway bridge. Here they are thick almost horizontal beds of blue slate—probably the corrugated trough of a geo-syncline. Fossils are common, but a very troublesome cleavage—common in nearly horizontal beds—makes extrac-

1 Geol. Castlemaine, op. cit.
2 Geol. Castlemaine, p. 66.

tion difficult, and specimens are poorly preserved. *Oncograptus upsilon* and varieties of *Didymograptus caduceus* occur as typical forms, and *Didymograptus v-deflexus* sp. nov. and *Trigonograptus* are also found. *Cardiograptus morsus*, nov. sp., is absent, which agrees with the evidence of other localities, and indicates that this form is characteristic of a higher horizon. *Oncograptus* occurs a little to the south on the same strike and in the creek bed half-a-mile to the north, and even north of this.

The next beds present some difficulty. Separated from the *Oncograptus* beds by recent deposits, but only 200 yards from them, typically Middle Castlemaine beds occur. *Phyllograptus typus*, J. Hall, and small forms of *Didymograptus caduceus*, being found in fair numbers in a narrow band of decomposed white slate. These beds also occur to the south, where they are succeeded on the west by Upper Castlemaine beds in the usual order. Along the railway the next beds are also Upper Castlemaine. As the evidence of other localities is very strongly against the Middle Castlemaine being within 600 feet of the *Oncograptus* beds, these Middle Castlemaine beds seem difficult to fit in. Faulting is apparently responsible for their juxtaposition. More than this statement the evidence does not warrant, but the common occurrence of slickensided faces and the experience of miners shows that faulting is common in these rocks. Between this outcrop and the 74-mile post Upper Castlemaine beds are found, and they are also well represented at the mile post. This zone again repeats, and then no fossils are found until Chewton is reached. Further search may reveal some, probably Middle Castlemaine, as such beds are exposed on the hills to the south and to the north (at Burns' Reef). Just past the Chewton Railway Station (75 miles) *D. bifidus* and *P. typus* re-appear on the summit of the Chewton ge-anticline on the strike of Dr. Hall's original Wattle Gully beds, Wattle Gully itself crossing the railway line immediately to the west. Higher beds—Middle Castlemaine—occur along the same strike at Quartz Hill north of the line, but southwards all the beds are either of the same horizon (Lower Castlemaine), or lower, as at Lost Gully (Daphne Reef) and Mount Eureka (The Monk), where Upper Bendigo beds outcrop. The Wattle Gully zone outcrops to the north in Cemetery Gully, and even further north in Dirty Dick's Gully. This is interesting, as the zone has seemingly never been previously recorded north of Forest Creek. At one spot a large variety of *D. bifidus*, with branches about 40 mm. in length, is found. The only other Castlemaine locality where it occurs is in Steele's Gully south of the

line. This northerly occurrence of *Didymograptus bifidus* marks the apex of a ge-anticline not shown in Messrs. Baragwanath or Herman's section. Several occurrences of *D. bifidus* between Chewton and 76½ miles indicate smaller anticlines. Near Aberdeen Hill, Middle Castlemaine beds are found, and then, after repetition, an ascending series of Upper Castlemaine between the Vincent Street bridge and the 77-mile post. The railway soon after this ceases to be of value, and the section has been worked out westward on less complete evidence. The most westerly occurrence of Middle Castlemaine beds noted in this locality is near New Chum Gully, though isolated outcrops may exist further west. With this exception, all graptolites found between a north and south line through the 77-mile post and the Harcourt-Campbell's Creek railway line are Upper Castlemaine.

So far the stratigraphical relations of the members of the Castlemaine series and some members of the Bendigo and a higher series, have been traced from the apex of a ge-anticline at the Elphinstone Tunnel exposing Upper Bendigo beds, through a syncline at 73½ miles, exposing beds containing *Oncograptus* and higher than the Castlemaine series, to the main apex of the Chewton ge-anticline exposing Wattle Gully (Lower Castlemaine) beds. These beds recur at intervals for about a mile, and then disappear under higher beds which rest on the western limb of this ge-anticline.

(*b*) *Water Race Section.*

Parallel to the whole length of the previous section and mostly within the same compass there is an almost complete section along the water race to the south. It is supplemented in part by outcrops along the ridge of hills between the race and the railway section already traversed in detail and by beds exposed south of the race on either side of the Chewton-Fryerstown Road.

Leaving the railway half way between the 72 and 73 mile posts, *Didymograptus bifidus* is first found, and after an unfossiliferous stretch, several Upper Castlemaine outcrops the first of which, as before mentioned, can be correlated with an outcrop on the railway. The beds then pass through Middle Castlemaine to Lower Castlemaine, several *D. bifidus* outcrops occurring between White Horse Gully and the Chewton-Fryerstown Road. From this road to the Monk the race is unfossiliferous, but at the Monk a small outcrop of the Bendigo series occurs, the beds on either side being still Lower Castlemaine. Between the Monk and the offtake of the South Campbell's Creek race

five outcrops yield *D. bifidus*, some also yielding a number of undescribed specimens. Another unfossiliferous stretch follows, but is in turn followed by the most prolific area in the district. In the area between Scott's Gully and New Chum Gully the outcrops are so numerous that they cannot well be shown on a map of small scale. The general succession from Middle to Upper Castlemaine is clear.

Sections Compared and Additional Data.

There are, then, in more or less detail, four lines of section along which the succession of beds from Upper Bendigo to Upper Castlemaine may be traced.

(a) That along the railway from Elphinstone Tunnel to Castlemaine, showing an ascent from Upper Bendigo to Upper Castlemaine and beyond, then a descent to Lower Castlemaine and a second ascent to Upper Castlemaine.

(b) That along the water race to the south, where the succession is the same, though more detailed.

(c) That along the hills between these two lines showing Middle and Upper Castlemaine beds.

(d) That east and west of the Chewton-Fryerstown Road, where the succession from the Upper Bendigo to Middle Castlemaine is well shown.

A fifth line along the South Campbell's Creek water race and hills from the Monk via Sebastopol Hill to Campbell's Creek shows an ascending series from Lower Castlemaine to Upper Castlemaine. From south of Fryerstown to the Limestone Creek the succession is from Lower or Middle Bendigo upwards, but an area between Guildford and Tarilta has not been examined. In addition a somewhat incomplete record is seen north of Forest Creek, and here the succession is the same. About the Vaughan-Tarilta "trap" area (Ba 80 and 81)[1] the beds pass from Upper Bendigo or transitional Wattle Gully (*T. fruticosus* and *D. bifidus*), to Middle Castlemaine as one goes west. The lowest beds in the district are those south of Fryerstown.

The evidence of all these sections is corroborative and supplementary, and, as they are parallel and contiguous, also cumulative. Few places offer more opportunity for checking one's work, and it is unthinkable that beds with a distinctive and foreign facies could exist between the Middle and Upper Castlemaine beds as distinguished by Dr. Hall and amplified here. The repetition of Middle and Upper Castlemaine beds to the east and west of Victoria

1 G.S. Vic., ¼ S., 15 S.W.

Gully especially leaves no room for doubt as to the succession of these beds.

X. Darriwil Series.

(As before stated, Dr. Hall's term Darriwil has been extended to include new beds.)

The stratigraphical position of the series, which has as its associated fossils *Trigonograptus*, sp., *Didymograptus caduceus* (Salter), *D. v-deflexus*, sp. nov., *Oncograptus*, spp., *Glossograptus*, sp., *Diplograptus gnomonicus*, sp. nov., and other forms as yet undescribed, is on the negative evidence afforded by the work of others and myself, above the Castlemaine series. The soundness of Dr. Hall's subdivision of the Castlemaine series, confirmed, as it is, by the work of Mr. T. S. Hart[1] at Daylesford and by my own at Castlemaine, permits of no other conclusion. With the exception of the outcrops mentioned (at 73½ miles), *Oncograptus* has not been found east of Castlemaine. To the west of the town the *Oncograptus* facies prevails, beds with *Oncograptus* or its associated forms being numerous and widespread. One of the most easterly outcrops is in a cutting on the Woodbrook Road near the north-west of the municipality of Castlemaine. The material taken from the cutting is very much decomposed and cleavage is troublesome. *Oncograptus upsilon*, T. S. Hall, is common, *D. caduceus* in most of its varieties is exceedingly common, and *T. serra*, Brong, is common. *Trigonograptus* is not uncommon, while *Diplograptus sp.*, and *Didymograptus v-deflexus*, sp. nov., are found. *Phyllograptus* does not seem to occur. *Diplograptus gnomonicus, sp. nov.*, may be present, but it is so delicate that even if it be present it is not likely to be found in the material available. Along the same line of strike the nearest beds are 1½ miles to the south, and are Upper Castlemaine. About 400 yards west of this Woodbrook Road locality another outcrop occurs in which *Phyllograptus* is common, and is there, as in some other parts of the district, and also at Steiglitz, associated with *Oncograptus*. Half-a-mile south of this second *Oncograptus* locality, and apparently on the same line of strike, fossils are to be found on the road east of the Sanitary Depot. A small excavation was made here and exposed beds that yielded *D. caduceus*, *Oncograptus upsilon* and *Trigonograptus* all in profusion. Further excavation would probably yield a larger variety. The species of *Trigonograptus* occurring in these beds is apparently not *T. wilkinsoni*, T. S.

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1 Proc. Roy. Soc. Victoria (n.s.), vol. xx. (1907), quoted by Hall, T. S., A.A.A.S. (1909), p. 319.

Hall, but *T. ensiformis*, J. Hall. I doubt if I have ever found *T. wilkinsoni*. A specimen of *Phyllograptus* was found in a fragment of rock, but not in situ. West of this locality similar beds are found, but not being well exposed, their graptolites cannot be given in detail, though *Oncograptus*, *D. caduceus*, *Diplograptus gnomonicus*, sp. nov., *Didymograptus v-deflexus*, sp. nov., and one specimen of *Glossograptus* may be recorded.

To the south is the Military Rifle Range. On it uppermost Castlemaine beds may be seen with characteristic forms, including *D. caduceus* and *Loganograptus logani*. In these beds an occasional *Oncograptus* may be found, but it is extremely rare. About 400 yards to the west of the Range there is a cutting on the Maldon line exposing thick beds of blue slate badly cleaved. *D. caduceus* and *Oncograptus upsilon* were obtained here, and a few yards to the south, on a small race, *D. caduceus*, *D. forcipiformis*, and *Goniograptus speciosus*, T. S. Hall. Still going west and a little south, the next beds, 300 yards further, on McKenzie Hill, yield a collection of forms difficult to specify; the beds are typically Upper Castlemaine. A rare *Trigonograptus* or *Oncograptus* may be found, but by far the most common form is *D. caduceus* and its varieties. This is the bed taken as typical of the *Logano-caduceus* (uppermost Castlemaine) zone, but though *Loganograptus logani* is common here, it is rare at other outcrops in the district.

The only other places where *Oncograptus* has been found in close relation to a recognised zone are near Yapeen and south of Guildford, and at both these places the nearest beds are Upper Castlemaine. West of these outcrops other forms are found and will be described, but Lower and Middle Castlemaine forms are conspicuously absent.

The field relations of the Darriwil beds near Yapeen and at Guildford and Woodbrook seem to indicate a high horizon for them. Along the line of strike in every case where fossils have been found they have been Upper Castlemaine. Occasional *Oncograptus* forms are found in Upper Castlemaine beds, and, as will be shown, there is a gradual progression from Upper Castlemaine through the *Oncograptus* beds to the original Darriwil zone.

(b) *Nature of Facies.*

A consideration of the *Oncograptus* facies involves the question of the subdivision of the beds of the series. The Bendigo and Castlemaine succession has long been known, but, while the graptolites of these two series are widely distributed, our knowledge of

Darriwil forms has been limited to those from one or two outcrops in the Darriwil district. As well preserved specimens are rare, the Darriwil forms are more difficult to identify specifically than those of lower horizons. While it was known that the Darriwil series was characterised by species of "*Tetragraptus*, *Didymograptus*, *Loganograptus*, *Diplograptus*, *Climacograptus*, *Glossograptus*, *Trigonograptus*, *Lasiograptus*, and others not determined,"[1] its exact relationship to lower beds had remained obscure and fossils found in other localities had thrown little light on the point. The presence of *P. typus*, J. Hall, with *Loganograptus* and large *D. caduceus* at Steiglitz was puzzling[2], and an assemblage of Newham forms "suggested the presence of both Darriwil and Castlemaine series."[3] The country to the west of Castlemaine had never been critically examined, and it was known to contain much that was new to the graptolite succession. Difficult forms found by officers of the Geological Survey half a century ago were still undescribed, and the chance of clearing away certain anomalies was deemed possible. It took time to acquaint oneself with these new forms, but having done so their order of development soon appeared. It soon became apparent that the beds could not be called Upper Castlemaine without altering the meaning of the term, nor for the same reason could they be called Darriwil, without widening the meaning of the term. The beds spread over an area of more than thirty square miles at Castlemaine, probably over a greater area at Macedon and Woodend, and south of Steiglitz, and occur also at Ingliston, Melton, and probably at other localities, and three zones seem to be recognisable.

In the Darriwil district all zones seem to be represented, the Upper or typically Darriwil, on Sutherland's Creek (W.L.S. 1, ¼ S.), and the lower or *Oncograptus* zone at Steiglitz.

In view of this all the beds, as already described, have been included in an extended series, for which the term Darriwil has been retained, and of which the previously known Darriwil beds form, as already stated, the upper zone. If, therefore, in earlier work "Darriwil" is read as "Upper Darriwil," no confusion will arise.

The vertical distance between the Middle and Upper Darriwil zones should be capable of measurement at Guildford, and they merge into one another through transitional beds.

No zone above that of *Tetragraptus fruticosus* has such a distinctive and characteristic association of species as these Darriwil

1 Hall, T. S., Australian Graptolites. Fed. Hbk. of Aust., B.A.A.S. (1914), p. 291.

2 Ibid., Reports on Graptolites, II. Rec. Geol. Surv. Vic., vol. iii., part 3 (1914), p. 290.

3 Skeats, E. W., and Summers, H. S., Geol. and Petr. Macedon District. Bull. Geol. Surv. Vic. 24 (1912), p. 41. Quoted from Hall, T. S., Geol. Surv. Vict. Prog. Rept., IX. (1898), p. 126.

beds: *Trigonograptus*, *Didymograptus v-deflexus*, sp. nov., and varieties of *Didymograptus caduceus*, range through all the series. *Oncograptus upsilon*, T. S. Hall, and *Diplograptus*, spp. indet., characterise the lower beds, *Cardiograptus morsus*, gen. et sp. nov., the middle beds, and *Diplograptus gnomonicus*, sp. nov., ranges through the Middle and Upper beds. *Strophograptus trichomanes*, Rued., also occurs. While it is impracticable in this part of the paper to discuss details of structure, a few points which will be dealt with more fully in the second part may be briefly indicated.

(a) The close resemblance of the thecae of *D. caduceus*, *Oncograptus*, and *Cardiograptus*[1] indicating a probable line of development.

(b) The progressive development in form of rhabdosome from *D. caduceus* to the Dicranograptid structure of *Oncograptus* and the biserial (?) *Cardiograptus*. *Diplograptus gnomonicus* may represent further development in the direction of simplification, for, while I have provisionally included it in the genus *Diplograptus*, its affinities with that genus are doubtful (Plate I., figs. 5 and 6). It may be of interest to note its close resemblance to a form figured by Ruedemann[2] as *Phyllograptus anna*, J. Hall. While these figures are given as of a phylogenetic, or senile, form of *Phyllograptus*, they differ from a typical specimen of that genus in (1) the presence of only two stipes. (Unless the drawings are misleading, the stipes normally shown as dark ridges along the medial plane, are absent, but a virgula is shown instead). (2) The more rapid alteration of the angle of inclination of the thecae. This will be seen by contrasting figs. 28 and 30 with others on the same plate. Except for the somewhat greater width the two figures bear a striking likeness to *D. gnomonicus*, which is certainly not a *Phyllograptus*. Another case of resemblance which may be more than a coincidence is presented by juvenile forms of *Oncograptus* and *Cardiograptus*, which recall the form described by Ruedemann[3] as *D. caduceus*, Salter, var. *nanus* (Plate I., fig. 9). Did the tendency, which in America ceased at this mutation, continue further and lead to the development of *Oncograptus* and *Cardiograptus*? It would appear not unlikely, for the horizon on which these forms are found seems to be that of *Diplograptus dentatus* in North America.

1 Since this paper was written Mr. R. A. Keble has intimated that after a close examination of Cardiograptus he has recognised a third branch which was probably at right angles to those on the plane of the laminae. Such a habit infers a phyllograptid structure which was hinted at by the late Dr. Hall in a verbal communication to the writer.

2 Grap. N.Y., I., pp. 715-716, plate 15, figs. 28 and 30.

Ibid., p. 698, fig. 90.

3 Grap. N.Y., p. 698, fig. 90.

(c) *Stratigraphical Horizon.*

Such being the forms present little doubt would have arisen as to the stratigraphical position of the beds but for the presence of *Phyllograptus* and *Goniograptus* which in this district were thought to have disappeared in the Middle Castlemaine[1] beds. In New Zealand, however, *Phyllograptus* is recorded in association with typical Upper Castlemaine (zone 1) forms[2]. The discontinuity of its range is therefore not so great as appears at first. (See Note 2 infra.) A similar anomaly with *Phyllograptus* is recorded by Ruedemann[3], who in a table showing the range of different species records *P. augustifolius* for Beds 1, 2, 3, and 6 of the Deep Hill Series, while he omits it from Beds 4 and 5. No possible arrangement of the beds will make all genera range continuously, and it must be left to later work to supply an adequate explanation. The polyphylogenetic origin of *Goniograptus* may be held to lessen the importance to be attached to its occurrence. To place the Victoria Gully Beds above the Darriwil Beds—which would be necessary to provide a continuous range for *Phyllograptus*—would break the continuity of the range for several other genera—for example, *Loganograptus*, *Trigonograptus*, *Oncograptus*, and *Glossograptus*. The fauna of the original or Upper Darriwil beds seems good evidence that these forms have been correctly placed, unless we are to suppose that these Darriwil beds are themselves Middle Castlemaine, a theory which I do not think sufficiently well supported to need combating. The presence of at least three genera of the Diplograptidae indicates a high horizon.

(d) *The Evidence from Didymograptus caduceus* (Salter).

The evidence to be derived from the study of the development of *Didymograptus caduceus* seems to point to a high position for

1 Geol. Castlemaine, op. cit.

2 Bell, J. M., Parapara Subdivision, N.Z. Geol. Surv. (n.s.), Bull., No. 3.

The forms recorded are said to be from one horizon, *Tetragraptus*, *Didymograptus*, *Loganograptus*, *Climacograptus* and *Phyllograptus* occurring on the same slab.

Figures are given of the following species—the comments in parentheses are mine.

Rastrites (obscure fragments which may or may not belong to that genus).

Didymograptus extensus (several figures representing two or more species of horizontal *Didymograptus*).

Tetragraptus quadribrachiatus (T. Serra).

Loganograptus octobrachiatus (non *L. Logani* vel *D. octobrachiatus*. An identical form is found in Upper Castlemaine beds here).

Phyllograptus typus.

Diplograptus sp.

Didymograptus caduceus (typically Upper Castlemainian (zone 1) form).

Climacograptus (doubtful identification).

3 Grap. N.Y., I., p. 506. (Bed 4 is omitted from the table throughout).

the Darriwil beds. Dr. Hall[1] states that in the Bendigo beds "*D. caduceus* is rare and small, and it is interesting to notice as we pass up through a long succession of rocks above these of Bendigo that it increases in relative numbers and at the same time attains a much larger size till it reaches its maximum near the horizon of the uppermost Castlemaine beds, where it crowds the rocks to almost entire exclusion of other forms. It then enters on the period of its decline, and is but sparingly represented by stunted forms at Darriwil, and perhaps ranges into the Upper Ordovician." Later Dr. Hall[2] expresses his doubt as to the occurrence of *D. caduceus* with *T. fruticosus*, and I have not found them together. With *D. bifidus*, *D. caduceus* is rare and small. In the Middle Castlemaine beds it is fairly common but small. In the Victoria Gully beds it is very numerous, and the specimens are larger than those of the lower beds. Here the rhabdosome is of horse-shoe shape, the stipes are of even width throughout, and a long nema is often present. In the McKenzie's Hill beds *D. caduceus* is even more common than in the Victoria Gully beds, where Dr. Hall[3] estimated it to comprise 80 per cent. of the fauna. In typical specimens from this upper zone the stipes diverge at the angle of about 330°, and the branches widen as they diverge and then narrow somewhat towards their distal extremities. The rhabdosome is now more like the letter V than U. In the beds west of McKenzie's Hill *D. caduceus* varies greatly, though it seems as if the maximum of variation is in the McKenzie's Hill beds. The stipes are longer than ever, but not so wide. Stipes measuring over 60 mm. in length are not at all uncommon. The forms of the two zones contrast in the same way as the tall thin-branched trees of a forest do with the sturdy, wide-spreading trees of the more open country. The contrast is not so great between the higher beds of the McKenzie Hill zone and the lowest *Oncograptus* beds. Measurements of twelve specimens on one slab from an outcrop near the Muckleford Railway Station, showed an angle of divergence varying from 315° to 335°, the average being 325°. Several of the specimens have stipes more than 60 mm. in length. *D. caduceus*, Salter var., *manubriatus*, T. S. Hall, and *D. forcipiformis*, Rued., both late derivatives of *D. caduceus*, are somewhat rare in the McKenzie's Hill beds, and more abundant in the western beds, being more common at some outcrops than at others. As Dr. Hall[4] noted, the thecal

1 Grap. Rocks of Vict., p. 443.

2 Recent Advances of our Knowledge of Victorian Graptolites. A.A.A.S. (1909), p. 319.

3 Geol. Castlemaine, p. 71.

4 Victorian Graptolites, Part IV. Proc. Roy. Soc. Victoria, xxvii. (n.s.), part i., 1914, p. 109.

characteristics of *Oncograptus* show its relation to *D. caduceus*, and it seems probable that *Oncograptus* and *Cardiograptus*, like *D. forcipiformis* and *D. caduceus var. manubriatus*, are also late derivatives of *D. caduceus*, and had a very limited range. Here, then, is the life history of *Didymograptus caduceus*. Originating when *D. bifidus* was flourishing in the Wattle Gully stage, or perhaps earlier, it outlived that form, and became fairly common in the Middle Castlemaine, as yet showing little if any increase in size. By the time the Victoria Gully stage was reached it had become by far the commonest species, and with favourable conditions reached its zenith in the McKenzie's Hill beds. The common fate of all genera and species now overtook it. It deployed in various directions giving rise to *Oncograptus*, *D. forcipiformis*, *Cardiograptus*, etc. It will be the purpose of the second part of this paper to attempt to show the phylogeny of these and other genera. If the Darriwil beds are placed anywhere but above the Castlemaine beds the development of *D. caduceus* becomes unintelligible.

(*e*) *Transitional Beds.*

Victorian graptolite zones are all based on the rise and fall of species. *T. fruticosus*, *D. bifidus*, and *D. caduceus* originated in that order, lived in association, and one by one disappeared, affording a basis for the subdivision of the rocks in which their remains are found. Dr. Hall[1] has shown how *T. approximatus*, Nich., occurring with Lancefield forms at Inglewood and Clarendon, and with Bendigo forms at Bendigo and in the Mornington Peninsula, indicates the highest beds of the Lancefield, or the lowest beds of the Bendigo series.

Now, *Oncograptus upsilon* and *Trigonograptus* occur similarly at Castlemaine. At McKenzie's Hill the majority of the forms are so characteristic of the Upper Castlemaine of Dr. Hall that I have taken them as typical of that zone—more typical even than McCoy's Barker Street beds, where *D. caduceus* is, on the whole, not so well developed. Yet at McKenzie's Hill *Oncograptus* and *Trigonograptus* are occasionally found, indicating the close proximity of the McKenzie's Hill beds to the Lower Darriwil series. At the Military Rifle Range *Oncograptus* is also found, though here again it is extremely rare, and the beds are typically Upper Castlemaine. The Rifle Range beds, as shown above, are found to be succeeded along their line of strike by *Oncograptus* beds, which, if one pre-

1 Recent Advances Vic. Graps., p. 319.

sumes the northerly pitch found elsewhere near Castlemaine, is what might be expected if the Lower Darriwil beds overlay immediately the Upper Castlemaine. In the same way, as *D. bifidus* succeeds *T. fruticosus*, *Cardiograptus morsus*, gen. et. sp. nov., is, at some localities, found with *Oncograptus upsilon*. Then *Oncograptus upsilon* disappears, and at Guildford beds containing *Cardiograptus morsus*, also contain *Diplograptus*, cf. *angustifolius*, and this latter form is common with Upper Darriwil forms in a neighbouring bed. This is also true of other undescribed forms.

(*f*) *Subdivisions.*

The manner in which the Upper Castlemaine beds merge into beds in which *Oncograptus* occurs has already been discussed. At each of the four outcrops mentioned, in which the nearest beds are Upper Castlemaine, *Oncograptus upsilon* occurs, and *Cardiograptus morsus* does not. If it were at all common in these beds sufficient exploration has been done at least at two of them to reveal it. *Cardiograptus morsus* has never been found in Upper Castlemaine beds. These facts seem to indicate that *Oncograptus upsilon* is representative of the lowest zone of the series. At Macedon, where the Lower Darriwil beds are well developed. *Cardiograptus morsus* appears to be absent, at any rate from some beds, if not from all.

At Castlemaine localities further west than those above mentioned *O. upsilon* and *Cardiograptus morsus* are found in association, both forms being common. At Guildford *O. upsilon* has not been found, though *Cardiograptus morsus* is common. This would suggest that *C. morsus* came in later than *O. upsilon* and outlived it, which is supported by the fact that on the Guildford-Strangways Railway the *Cardiograptus* beds occur both east and west of typically Upper Darriwil beds. These *Cardiograptus* beds contain at least one species, *D. cf. angustifolius*, otherwise restricted to the neighbouring Darriwil. The Upper Darriwil beds at Guildford contain *Loganograptus*, *Diplograptus cf. angustifolius*, *D. caduceus* (varieties), *Diplograptus gnomonicus*, sp. nov., *Trigonograptus*, *Lasiograptus*, *Glossograptus*, and *Didymograptus v-deflexus*, sp. nov. No genus found at the typical Upper Darriwil locality (W.L.S. 1, ¼ S., 19 S.W.) is wanting here, except *Climacograptus*, and even at Darriwil *Climacograptus* does not appear to be common, as an examination of slabs in the National Museum, Melbourne, failed to reveal any specimen of the genus. At Darriwil, also (W.L.S. 2 and W.L.S. 3) *Cardiograptus morsus* is found, but not near enough to W.L.S. 1 to render exact correlation possible. It is instructive to find that

there it also occurs apparently without *O. upsilon*, though the latter occurs without it further north, near Steiglitz, as already noted.

(*g*) *The Series in other Localities.*

Most of the localities from which, as far as the writer knows, Darriwil graptolites have been obtained, have already been mentioned. They may be summarised as under :—

(1) Between Castlemaine and Muckleford Creek, and south-west of Guildford. (Lower, Middle, and Upper).

(2) At Woodend (eight miles S.W. of Woodend) and Macedon. (Lower.) (They are well represented north of Old Gisborne township, and along the railway south of Macedon R.S.), and at Newham (Upper?).

(3) Near Ingliston, and perhaps at Coimadai and Melton (Lower).

(4) At Steiglitz (Lower).

(5) South of Steiglitz (W.L.S. 2 and W.L.S. 3, $\frac{1}{4}$ S., 19 S.W.), parish of Coole Bharguk (Middle), and at Darriwil (W.L.S. 1) (Upper).

XI. Summary of Conclusions.

The proposed revised classification is the outcome of a critical examination of a number of sections and localities in which the stratigraphical relations of the beds are those given in the stratigraphical table.

This stratigraphical table shows :—

(a) An agreement in general with Dr. Hall's subdivision of the Castlemaine series.

(b) A new series above the Castlemaine series and between it and including the Darriwil beds of Dr. Hall. This is described as the Darriwil series.

(c) A subdivision of this extended Darriwil series into three zones based on the rise and fall and the association of certain described species and new species (to be described in Part II. of this paper).

(d) A record of the Upper Darriwil series at Guildford.

The stratigraphical position, nature of facies, the evidence supplied by *D. caduceus*, and a list of localities where the Darriwil series is known to occur in other parts of the State of Victoria, have been given in more or less detail.

The country examined to obtain the evidence necessary to erect this new series comprises that already examined by Dr. Hall and a

considerable area outside it. The first section given in this paper differs in certain important respects from those of Messrs. Baragwanath and Herman, and the extent of favourable auriferous beds —those in the vicinity of the Chewton ge-anticline appear to be more auriferous than others—is increased.

Bendigonian beds some distance down in the series are shown to occur near Fryerstown, and the succession on every side of the "dome" clearly indicates the pitch.

A map showing the general arrangement of the beds and more than 150 localities visited is given.

Acknowledgments.

In conclusion, I wish to express my indebtedness to all who have assisted me. To the late Dr. T. S. Hall in particular I owe much for placing at my disposal literature and specimens in his possession and for an always kindly interest in my work. His death has deprived the scientific world of its greatest authority on Australian graptolites. Mr. F. Chapman, A.L.S., Palaeontologist of the National Museum of Victoria, has assisted me by elucidating the cryptic symbols on the old Geological Survey plans and by permitting me to examine more closely than would otherwise have been possible specimens collected by officers of the Survey now in the possession of the Museum. From Mr. H. Herman, Director of Geological Survey, and officers of the Mines Department of Victoria, I have received valuable assistance. The re-drawing of plans, etc., has been carried out by the latter in a manner far superior to anything I could have done personally. Mr. R. A. Keble, of the Mines Department, in particular, has been in touch with my work since its beginning, and, besides making many valuable suggestions, has been kind enough to read through the manuscript and assist in moulding it to a publishable form. Dr. Rudolf Ruedemann very kindly forwarded me, through the Smithsonian Institute, his monograph on the "Graptolites of New York," a work of the value of which it is unnecesary for me to speak. It is impossible in any list such as this to do justice in detail to all who have assisted, so I conclude by thanking collectively all who have helped me. For the accuracy of observations and conclusions contained in this paper and not ascribed to others I must hold myself personally responsible.

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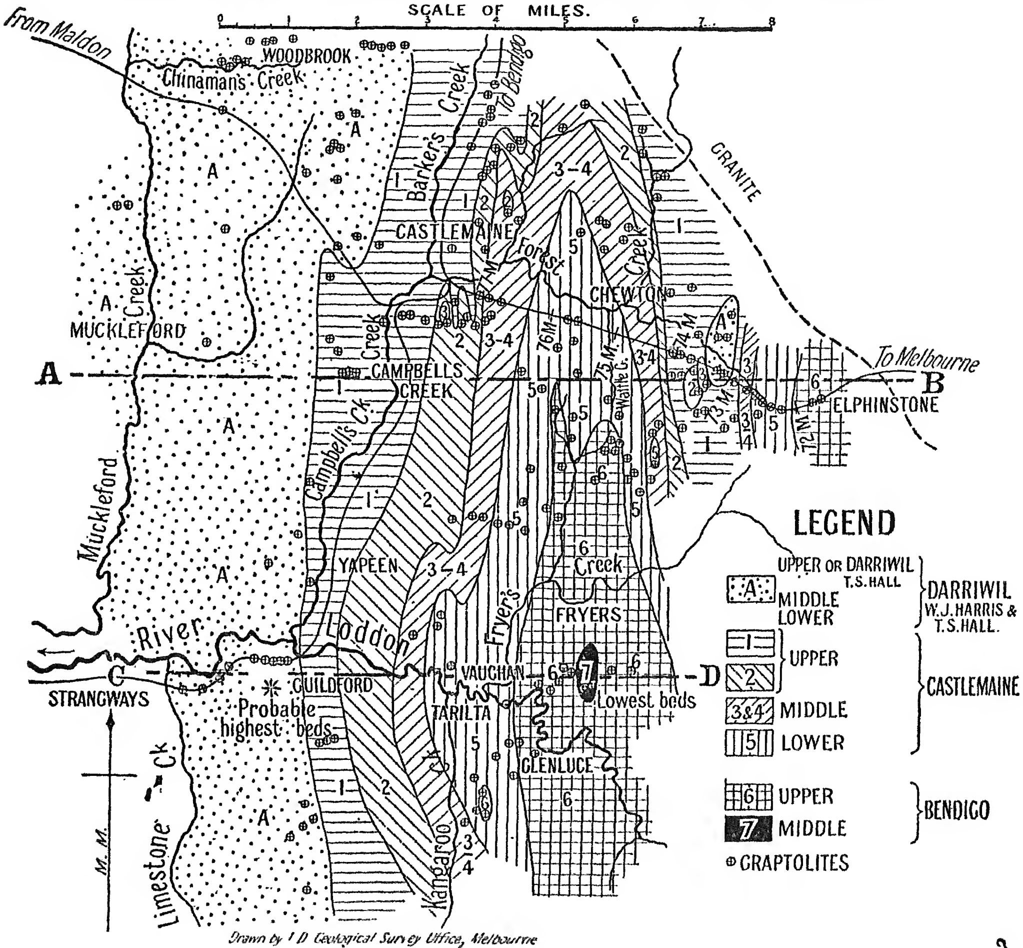
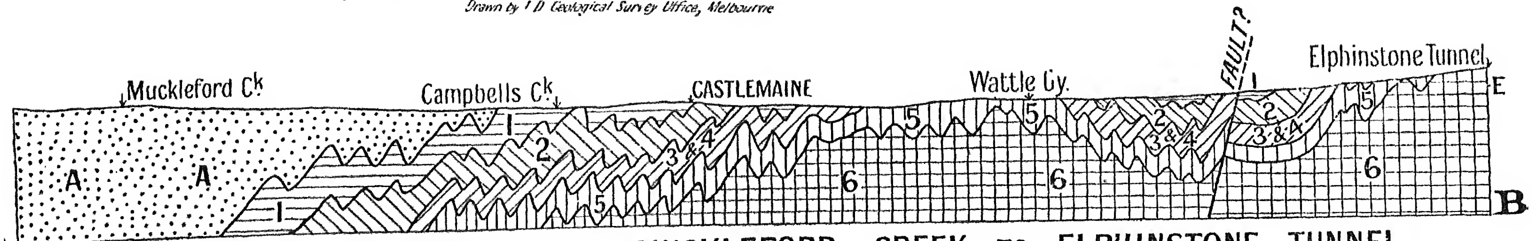
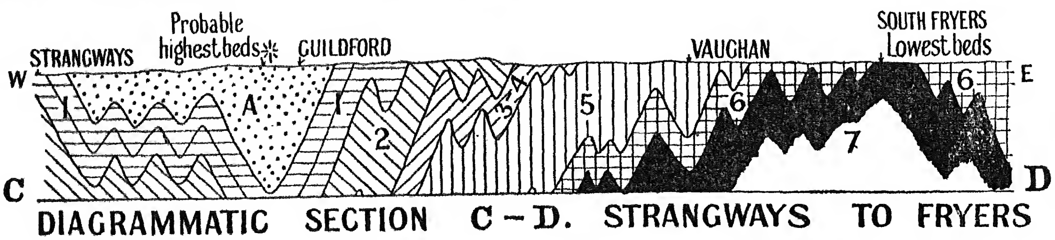




DIAGRAMMATIC SECTION A–B. MUCKLEFORD CREEK TO ELPHINSTONE TUNNEL.



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EXPLANATION OF PLATE I.

(New species figured by W. J. Harris and R. A. Keble).

Fig. 1.—Cardiograptus morsus, gen. et sp. nov. narrow form. × $\frac{3}{2}$. Chinamen's Creek, Q.S. 15 N.W., Note 6.

2.—C. morsus. Another specimen showing typical shape of rhabdosome. × $\frac{3}{2}$. Same locality.

3.—C. morsus. Another specimen, slightly enlarged. Same locality.

4.—C. morsus. A juvenile form showing sicula; lines somewhat hardened to portray structure. × 3. Same locality.

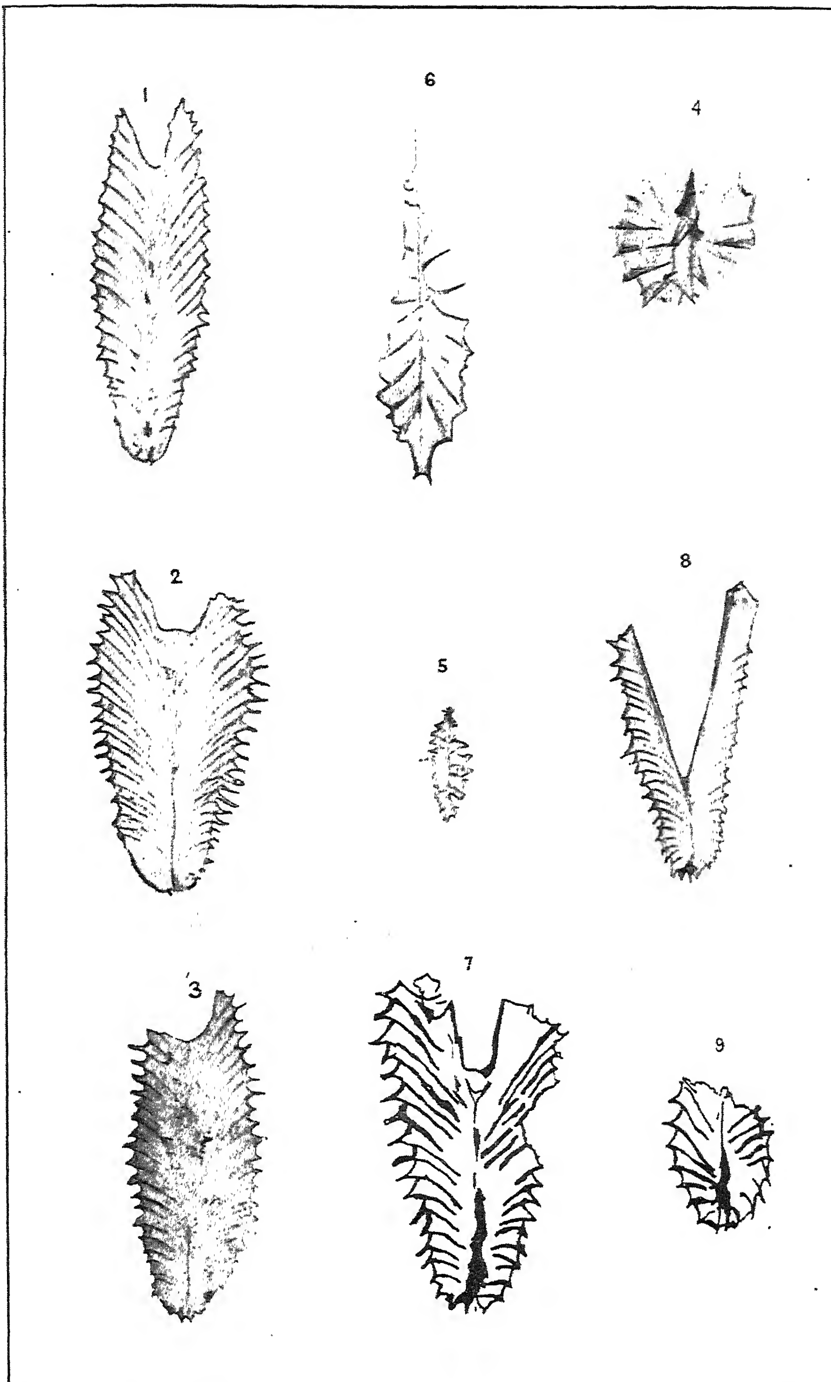
5.—Diplograptus gnomonicus, sp. nov. Typical preservation facies, the reversal of the direction of the thecal walls is indistinctly shown. × 2. Same locality.

6.—D. gnomonicus (mag). Figure shows varying inclination of thecae. × 6. Same locality.

7.—Oncograptus biangulatus, sp. nov. Proximal end of rhabdosome. × $\frac{5}{2}$. Same locality.

8.—O. biangulatus. Typical rhabdosome. × $\frac{3}{2}$. Same locality.

9.—O. biangulatus. Juvenile form. × 2. Same locality.



W.J.H. & R.A.K. Del.

[Proc. Roy. Soc. Victoria, 29 (N.S)., Pt. I, 1916]

Art. V.—*New or Little-known Victorian Fossils in the National Museum.*

Part XIX.—The Yeringian Gasteropod Fauna.

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(With Plates II.-VI.).

[Read 13th July, 1916].

Introductory.

Of late years a considerable number of Silurian gasteropods have been added to the collection of the Melbourne National Museum, chiefly through the assiduous work of collectors whose names are mentioned in the body of the text, and who have permitted the Museum to benefit by their discoveries. Amongst the more notable genera of Silurian gasteropods herein described are:—*Helcionopsis*. *Temnodiscus*, *Carinaropsis*, *Cyrtostropha*, *Craspedostoma*, *Orthonychia*, *Diaphorostoma* and *Hercynella*, all of which appear to be new to the Southern Hemisphere.

Coelocaulus is here used to replace *Niso* (*Vetotuba*); the murchisonian affinities of the Cave Hill specimens being clearly shown in the Museum examples. The wide area of distribution for this genus in palaeozoic times is thereby extended into the Australian region. A new genus, *Liomphalus*, is herein suggested for smooth euomphalid shells with biconcave surfaces and partially open whorls.

A noteworthy feature of the Yeringian fauna is the comparative abundance of gasteropoda in contrast with their rarity in the Melbournian. The complete list of Yeringian gasteropods comprises 36 species, whilst there are only six species known up to the present time in the Melbournian. This gives a deeper water aspect to the Yeringian sea as a whole, and is concomitant with the data derived from the lithological structure and general stratigraphy of the two groups of beds in question.

So large a proportion of the Victorian Yeringian gasteropods is here described for the first time, comprising sixteen new species, and a variety, that it seemed advisable to make this paper a complete record of all the Yeringian species, so far as the material is sufficiently well preserved for descriptive purposes.

LIST OF YERINGIAN GASTEROPOD FAUNA.

Name.	Lilydale (limestone or mudstone).	Loyola (limestone or mudstone).	Upper Yarra.	Kilmore.	Other Localities.
Helcionopsis nycteis, Cressw. sp.	L				
Helcionopsis elegantulum, sp. nov.	L				
Temnodiscus pharetroides, sp. nov.		M			
Trematonotus pritchardi, Cressw.	L				Thomson R.
Bellerophon fasciatus, Lindström			X		
Bellerophon aff. *fastigiatus*, Lindström				X	
Bellerophon cresswelli, Eth. fil.	L				
Bellerophon pisum, sp. nov.	L				
Carinaropsis victoriae, sp. nov.	M				
Pleurotomaria maccoyi, sp. nov.			X		
Mourlonia duni, Eth. fil.				X	
Mourlonia subaequilatera, sp. nov.	L				
Phanerotrema australis, Eth. fil.	L				
Coelocaulus brazieri, Eth. fil. sp.	L				Marble Cr.
Coelocaulus apicalis, sp. nov.	L				
Cyrtostropha lilydalensis, sp. nov.	L				
Goniostropha pritchardi, Eth. fil.	L				
Gyrodoma etheridgei, Cressw. sp.	L				
Euomphalus centrifugalis, sp. nov.		M	X		
Euomphalus northi, Eth. fil. sp.	L				
Liomphalus australis, sp. nov.	L				
Straparollus debilis, sp. nov.	M				
Omphalotrochus globosum, Schlotheim sp.	L				
Scalaetrochus antiquus, Cressw. sp.	X		X		
Scalaetrochus lindstroemi, Eth. fil. sp.	L				
Craspedostoma lilydalensis, Cressw. sp.	L				
Cyclonema lilydalensis, Eth. fil.	L				
Cyclonema australis, Eth. fil.	L				
Loxonema sinuosa, Sow. sp., var. *australis*, nov.	L				
Orthonychia brevis, sp. nov.		L			
Platyceras minutum, sp. nov.					Deep Creek (Thom. R.)
Platyceras cornutum, Hisinger		L M			
Platyceras erectum, J. Hall sp.					Kilmore D.
Diaphorostoma retrorugatum, sp. nov.	M				
Diaphorostoma incisum, sp. nov.					Thomson R.
Hercynella victoriae, sp. nov.			X		

DESCRIPTION OF THE SPECIES.

Fam. ACMAEIDAE.

Genus **Helcionopsis**, Ulrich and Scofield.

Helcionopsis nycteis, Cresswell sp. (Plate II., Fig. 1).

Tryblidium nycteis, Cresswell, 1893. Proc. Roy. Soc. Victoria, vol V. (N.S.), p. 41, pl. IX., fig. 4.

Capulus nycteis, Cresswell sp., Chapman, 1913. Rep. Austr. Assoc. Adv. Sci., vol. XIV., p. 227.

Description.—Shell sub-ovate, strongly convex along the back, broadening and expanding towards the sides. Form resembling a strongly-arched *Crepidula*. Apex slightly overhanging the pre-apertural area. Side view plano-convex, highest at the middle point between the apex and ventral edge. End view semi-ovate, with a slight cant towards one side. Lines of growth marked by numerous raised concentric ridges, the interspaces relieved by radial striae. Lines of growth in middle of shell about .5 mm. apart.

Dimensions.—Holotype. Length, 31 mm.; greatest width, 20 mm.; height, from back of shell to ventral edge, 15 mm.

Observations.—This shell was originally referred to *Tryblidium* by Mr. Cresswell on account of its resemblance to some Gotland forms described by Lindström. The Gotland specimens are more depressed, with the exception of one species, referred doubtfully to *Tryblidium*,[1] and which appears to belong to *Helcionopsis*, and somewhat related to the above species.

The present writer referred this species to *Capulus* in 1913, on account of the asymmetrical apex, but in the light of the structure shown in the next species described, the relationship appears to be with *Helcionopsis*.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Holotype presented by the Rev. A. W. Cresswell, M.A.

Helcionopsis elegantulum, sp. nov. (Plate II., Figs. 2, 3; Plate VI., Fig. 49).

Description.—Shell sub-ovate, one and a-half times as long as broad; apex acuminate but not prominent; sides gently rounded, back highly arched near apex and depressed convex near ventral border. Growth-lines lamellate and situated about 1.5 mm. apart in the middle of the shell; interspaces marked with numerous radial

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1 (?) *Tryblidium radiatum*, Lindström. Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 58, pl. xviii., figs. 1, 2.

riblets, which extend over the edge of the lamellae where well preserved.

Dimensions.—Length, 20 mm. Approximate width when complete, 15.5 mm. Greatest height from ventrum to dorsum, 10 mm.

Observations.—This distinct species is easily separated from the earlier named Victorian form, *H. nycteis*, in the more spacious concentric ornament, its lamellate character, and in the more evenly rounded dorsum.

H. elegantulum is closely allied to *H. eminens*, Barrande sp.[1] from the Lower Devonian (Etage F), Konieprus, Bohemia. It differs from that species in having a more narrowly ovate and higher shell, and agrees in the lamellate and radial ornament.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Holotype presented by Mr. J. S. Green.

Fam. Cyrtolitidae

Genus **Temnodiscus**, Koken, 1896.

Temnodiscus pharetroides, sp. nov. (Plate., II., Figs. 4, 5; Plate VI., Figs. 50, 51).

Description.—The Victorian specimen is in the form of a cast. It shows the compressed initial coil with rapidly widening body-whorl. The latter is expanded on the inner side. The slit-band is keel-shaped and prominent, and the surface of the shell is ornamented with concentric rugae.

Dimensions.—Diameter, 8 mm.; width of last whorl, 6.5 mm.; width of mouth, 8 mm.

Observations.—In form this species resembles Lindström's "*Cyrtolites*" *pharetra*,[2] of the Silurian of Gotland, with the exception that the Victorian species is wider across the mouth at the inner part of the body whorl, its keel is sharper and more salient, and the concentric ornament more rugose.

Another somewhat allied species is Perner's *Temnodiscus ferrigena*,[3] from which the Victorian species differ in the greater umbilical diameter and the more discoidal outline. The ornament in the Bohemian species consists of finely striate growth-lines, as

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1 Perner, in Barrande's Syst. Sil. Bohême, vol. iv., tome i., 1903, p. 37; tome ii., 1907, pl. civ., figs. 13-15 and fig. 10 in text.

2 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 83, pl. vi., figs. 39-51.

Note.—Some of Lindström's species referred to *Cyrtolites* properly belong to *Oxydiscus*, as pointed out by Koken—Bull. Acad. Imp. Sci. St. Petersb., ser. v., vol. vii., 1897.

3. In Barrande's Syst. Sil. Bohême. vol. iv., tome i., 1903, p. 78, fig. 54 in text; tome ii., 1907, pl. cxiv., figs. 5, 6.

contrasted with the more rugose character of those in *T. pharetroides.*

Occurrence.—Silurian (Yeringian). In ochreous mudstone, Loyola, near Mansfield. Collected and presented by Mr. G. Sweet, F.G.S.

Fam. BUCANIIDAE.

Genus Trematonotus, J. Hall,

Trematonotus pritchardi, Cresswell.

Tremanotus pritchardi, Cresswell, 1893. Pro. Roy. Soc. Victoria, vol. V. (N.S.), p. 42, pl. VIII., fig. 1.

Trematonotus pritchardi, Cresswell, Chapman. 1913. Rep. Austr. Assoc. Adv. Sci., vol XIV., p. 227.

Observations.—This species shows some marked resemblances to the Gotland form, *T. longitudinalis*, Lindström.[1] The Victorian species has a more regularly planorbid spiral shell, which is not anteriorly elongated as in *T. longitudinalis.* The interior of the aperture is almost smooth in *T. pritchardi*, whilst the longitudinal spiral lines are undulose, producing with the concentric lines of growth a decided fenestration. A medium-sized example from the Thomson River, Gippsland, has the perforations in the slit-band rather larger than in the Lilydale specimens, and the spiral lines are decidedly more flexuous.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A. Thomson River, Gippsland, 3½ miles N.W. of Mt. Lookout; presented by Mr. G. T. Lovat.

Fam. BELLEROPHONTIDAE.

Genus Bellerophon, Montfort.

Bellerophon fasciatus, Lindström. (Plate II., Fig. 6; Plate VI., Fig. 52).

Bellerophon fasciatus, Lindström, 1884. Kongl. Svenska Vet.-Akad. Handl., Bd. XIX., No. 6, p. 75, pl. VI., figs. 13, 14.

Observations.—The Victorian specimen agrees with Lindström's form in having a compressed shell which is hardly umbilicate, and an inconspicuous and blunt keel; the growth lines are gently sinuous.

1 Kongl. Svenska Vet.-Akad. Handl. Bd. xix., No. 6, 1884, p. 86, pl. iii., figs. 39, 40; pl. iv., figs. 1-7.

Occurrence.—Silurian (Yeringian). In brown mudstone, junction of the Woori-Yallock and the Yarra. Coll. of the Geol. Surv. of Vict. (B23.)

Bellerophon aff. *fastigiatus*, Lindström. (Plate II., Figs. 7, 8).

Bellerophon fastigiatus, Lindström, 1884. Kongl. Svenska Vet.-Akad. Handl., Bd. XIX., No. 6, p. 76, pl. VI., figs. 1-10.

Observations.—A complete cast of a subspherical *Bellerophon* occurs in the Yeringian mudstone of Kilmore. In the moderate compression of the dorsum, the faint keel and conspicuous and fairly narrow umbilicus, it is very close to Lindström's species from the Silurian of Gotland. Probably better preserved specimens will show it to be a new species allied to the northern one.

Dimensions.—Greater diameter, 13.5 mm.; shortest diameter, 11 mm. Width of aperture near base of whorl, 9.5 mm.; height of aperture, 5 mm.

Occurrence.—Silurian (Yeringian). Kilmore. Collected and presented by Mr. G. Sweet, F.G.S.

Bellerophon cresswelli, Etheridge fil. (Plate II., Fig. 12; Plate VI., Fig. 53).

Bellerophon cresswelli, Etheridge, jnr., 1891. Rec. Aust. Mus., vol. I., No. 7, p. 130, pl. XIX., figs. 6-8.

Observations.—This species has already been compared with *B. squamosus*, Lindström,[1] by Mr. Etheridge in his original description, where he states that the shell is not fenestrate as in the Gotland species. It is worth noting, however, that a well preserved specimen in the National Museum shows a faint but definite lattice structure of wavy striae across the growth-lines. The form of the earlier portion of the shell is so distinctly globular that this feature alone separates it from *B. squamosus.*

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A., and others.

Bellerophon pisum, sp. nov. (Plate II., Figs. 9-11).

Description.—Shell almost globular, umbilical depression small, moderately deep. Aperture low, sub-crescentic, about four times as broad as high. Growth-lines making a widely open V in the band area. Sinus band distinct, narrow, slightly raised from the surface. Surface of shell marked with interrupted radial striae, seen distinctly between the lines of growth.

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1 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 78, pl. v., figs. 17-24.

Dimensions.—Height, 11.25 mm. Width, 10 mm.

Observations.—Lindström has figured a small *Bellerophon* (*B. pilula*) from Gotland,[1] which is even of smaller dimensions than the Victorian, and which is of the same globular shape. Lindström's species differs in the minute but clearly fenestrate ornament which in ours is apparently evanescent on the growth-lines, and also in the weaker sinus band.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A.

Genus **Carinaropsis**, J. Hall.

Carinaropsis victoriae, sp. nov. (Plate II., Figs. 13, 14).

Description.—Shell patelloid, ovate, transversely elongate. Spire prominent, narrowly rounded, depressed on the shoulders and rapidly widening and expanding to the depressed subcircular body cavity. Dorsum moderately convex, and depressed towards the ventral and lateral margins. Surface relieved with shallow sulcate growth-folds and numerous radial folds or shallow riblets. Inner surface shows a thick, broad, umbonal platform, beneath which is a shallow groove corresponding to the carina on the external surface.

Dimensions.—Holotype.—Diameter from spire to ventral margin, 18.25 mm. Extreme width, 22.75 mm.

Paratype.—Diameter from spire to ventral margin, circ. 21 mm. Extreme width, 24 mm.

Observations.—The present species is nearly related to *Carinaropsis ithagenia*, Clark,[2] a fossil of the Ithaca fauna, of Upper Devonian age. The only differences existing between these forms are the more salient spire, the depressed and more obliquely sloping shoulders, and the more irregular growth-lines in the Victorian species.

Occurrence.—Silurian (Yeringian). In olive-brown mudstone, Ruddock's Quarry, near Lilydale. Holotype coll. R. H. Annear. Paratype presented by Mr. J. S. Green.

Fam. Pleurotomariidae.

Genus **Pleurotomaria**, Sowerby.

Pleurotomaria maccoyi, sp. nov. (Plate II., Figs. 15-17).

Description.—Shell trochoid, moderately high, the width and height being nearly equal. Apical angle 80 deg. Whorls about six

1 Tom. supra cit., p. 80, pl. vi., figs. 29, 30.

2 New York State Mus., 57th Ann. Rep., Mem. 6, 1904, p. 323 (footnote), pl. xvi., figs. 18-20.

in number, subangulate and rounded, more convex below than above. Slit band prominent, projecting beyond the contour of the whorls, and bounded above and below by a raised border; surface gently concave, with four crescentic growth-lines in a millimetre. Base moderately convex; umbilicus open. Mouth, subovate. Surface of whorls traversed by close and fine growth-lines, curving backwards to the band above, with a sigmoidal forward and backward curve below. Fine cross-lines between growth-lines visible in a strong light.

Dimensions.—Height about 27 mm. Width at base about 30 mm. Height of body whorl, 18 mm. Width of slit-band, 1 mm. Most of the specimens are more or less distorted, but being fairly numerous, an accurate average idea may be formed of the dimensions.

Observations.—This striking species is not far removed from McCoy's *P. crenulata*, from the Upper Ludlow, of Brigsteer, Kendal, Westmoreland.[1] It differs in the larger number of whorls, in their more depressed contour and in the less deeply incised suture; moreover, the band in *P. maccoyi* is not concave as in the English species.

Another closely related form is Lindström's *P. claustrata*,[2] from the Wenlockian, of Gotland, which resembles the Victorian species in proportionate height and width, in the number of whorls and in the general ornament, with the specific difference that the growth-lines on the whorls of *P. maccoyi* have a distinctly sigmoidal sweep, whereas in *P. claustrata* they are more gently curved. The latter form also has a more excavated slit-band.

The above described examples of *P. maccoyi* were selected many years ago by McCoy from a collection of Survey fossils, and placed in the Museum under the name of *Pleurotomaria*, but without further reference. The species is now identified with his name in honour of his classical work on the gasteropods of the British palaeozoic system.

Occurrence.—Silurian (Yeringian). Moderately common in olive-brown and blue mudstone, from the junction of the Woori-Yallock and Yarra, Upper Yarra district. G.S.V. (B23).

Genus **Mourlonia**, de Koninck.

Mourlonia duni, Etheridge fil.

Mourlonia duni, Etheridge, jnr., 1898. Rec. Austr. Mus., vol. III., No. 4, p. 73, pl. XV., fig. 5; pl. XVI., fig. 2.

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1 Brit. Pal. Foss., 1855, pt. ii., p. 291, pl. i., k, fig. 45.

2 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 97, pl. vii., figs. 31-36.

Observations.—This shell was described by Etheridge from the Wellington Caves, New South Wales, and recorded as of Siluro-Devonian age.

The species is not uncommon in the Yeringian series of Victoria. As far back as 1902 I identified it in the Museum collection. Owing to the overlapping of the locality numbers used on the early Victorian Geological Survey specimens, this species was erroneously recorded in my list of Silurian Fossils of Victoria,[1] as from "Anderson's Creek," but which should read "Police Paddock, Kilmore," a locality that has yielded a number of Yeringian species.

Occurrence.—Silurian (Yeringian). In brown, sandy mudstone, Police Paddock, Kilmore, G.S.V. Bb 22. Also a form with flatter whorls, but evidently belonging to the same species; in similar rock, Fraser's or No. 3 Creek, Springfield, G.S.V. Bb 25.

Mourlonia subaequilatera, sp. nov. (Plate III., Figs. 18, 19).

Description.—Shell heliciform. Whorls six or seven, convex, sutures distinct. Slit-band slightly above the median line, narrow, bordered by prominent threads above and below. Whorls ornamented with strong, raised costae, above arcuate and inclined forward to the mouth, and vertically arcuate below. Area between costae finely striate, at right angles to them. Spire low, with pointed apex. Base in the holotype encrusted, but with indication of a wide umbilicus.

Dimensions.—Greatest breadth of shell about 26 mm. Height, from base to apex, 15.5 mm.

Observations.—The above species appears to belong to de Koninck's genus *Mourlonia*, which is a conical or discoidal pleurotomarid with distinct umbilicus. A closely allied species is *Mourlonia aequilatera*, Wahlenberg sp.,[2] a well-distributed Upper Silurian fossil in Europe. The Australian species differs in having the slit-band superior to the median line, and in the costae being more pronounced and intercancellate.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A.

Genus **Phanerotrema**, Fischer.

Phanerotrema australis, R. Etheridge fil. (Plate III., fig. 25).

Phanerotrema australis, R. Etheridge, jnr., 1891. Rec. Austr. Mus., vol I., No. 7, p. 128, pl. XIX., figs. 4, 5.

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1 See "*Pleurotomaria (Mourlonia) duni*, Eth. fil." Rep. Austr. Assoc. Adv. Sci., Melbourne Mtg., 1913, vol. xiv., p. 218.

2 *Helicites aequilatera*, Wahlenberg. Petrifacta Svecana Telluris, 1818, p. 73. *Pleurotomaria aequilatera*, Wahl. sp. Lindström, Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 111, pl. ix., figs. 20-29.

Observations.—This large and handsome form of the pleurotomarid group bears close relationship with both *Phanerotrema balteata*, Phillips sp.,[1] from the Wenlock series, and *P. labrosa*, J. Hall sp.,[2] from the Lower Helderberg series. By the discovery of a fine, nearly complete specimen of *P. australis* in the Cave Hill limestone by Dr. E. Brooke Nicholls, it is possible to add some notes of interest to the original diagnosis of the less complete specimen described and figured by Mr. Etheridge.

Dimensions.—Height from base of columella to apex of whorls, 92 mm.; greatest width of shell, 90 mm. Height of penultimate whorl, 13 mm. Height of last whorl, 68 mm. Approximate width of aperture, 55 mm.; approximate length, 66 mm. Distance of slit-band from base of shell, 50 mm. Distance of slit-band from last suture, at mouth, 37 mm. Width of slit-band at mouth, 6.5 mm.

Comparisons.—Body whorl—Depressed and even slightly concave as in *P. labrosa*. In *P. balteata* it is gently convex. Spire—Moderately well developed as in *P. balteata*. Sutures—Deeply channelled as in *P. balteata*.

The Australian species appears to exceed in size any other of this group, and as remarked by Mr. Etheridge, is a more obliquely elongated shell.

Occurrence.—Silurian (Yeringian). In friable limestone,[3] Cave Hill, Lilydale. Presented by Dr. E. Brooke Nicholls.

Fam. MURCHISONIIDAE

Genus **Coelocaulus**, Oehlert.

Amongst Silurian *Murchisoniidae* there occurs a peculiar generic type of shell characterised by its turrited form, with flat whorls, especially in the earlier stages, and a conspicuous, persistent umbilicus. This type of shell is widely distributed, occurring in various Silurian faunas of Europe, North America and Australia. The slit-band is often obscure in shells of this type where the later whorls are not preserved, but in specimens where the last two whorls are found, the latter are subangularly convex with an infra-median slit-band, and show a relationship to the genus *Hormotoma*, Salter, as emended and typified by Mrs. Longstaff (Miss Jane Donald),[4] in the species *H. cingulata*, Hisinger[5]

1 (*Pleurotomaria balteata*). Mem. Geol. Surv. Gt. Brit., vol. ii., pt. i., 1848, p. 358, pl. xv., figs, 1, 2.

2 (*Pleurotomaria labrosa*). Pal. N. York, vol. iii., 1859, p. 339, pl. lxvi., figs. 1-5.

3 This matrix is a calcareous sand composed of granules largely of algal origin, together with fragments of crinoids.

4 Quart. Journ. Geol. Soc., vol. lv., 1899, p. 257.

5 *Turritella cingulata*, Lethaea Svecica, 1837, p. 39, pl. xii., fig. 6.

Although related to *Hormotoma* by the form of the later whorls and the position of the slit-band, the open and persistent umbilicus is a very distinct feature in the shells under notice. Consequently forms of this type of Devonian age were generically separated as *Coelocaulus* by Oehlert in 1888.[1] In 1897 Ulrich[2] referred the Onondaga (Silurian) species, *Murchisonia logani*, to the same genus.

Coelidium was more recently suggested as a genus name to replace *Coelocaulus* by Clarke and Ruedemann,[3] but has not been adopted, even in America, apparently on insufficient grounds of pre-occupation.

The Australian Silurian and Devonian faunas both contain representatives of this interesting genus. In 1877 de Koninck described a Devonian species from the Yass district in New South Wales under the name of *? Niso darwinii*,[4] a form which undoubtedly species congeneric with de Koninck's, from the Silurian of Cave belongs to this genus. In 1890 Mr. R. Etheridge, jnr.,[5] described a Hill, Lilydale, Victoria, to which he gave the name *Niso (Vetotuba) brazieri*, at the same time remarking on the close correspondence between de Koninck's and his species.

Whilst examining some senile forms of the Lilydale specimens of this type, and in particular one found by Mr. J. S. Green, I noticed the presence of a sinus-band in the later whorls which confirmed a determination as *Murchisonia* made many years ago by McCoy on a Museum specimen presented by Dr. G. B. Pritchard.

Referring in this place to other occurrences of *Coelocaulus*, we may note Lindström's Silurian example—"*Murchisonia*" *compressa*[6] from the Silurian of Gotland, which has a similar wide and open umbilicus extending apparently to the apex.

The Upper Silurian of Petropaulowsk in the Russian Oural appears to contain examples of this genus, represented by "*Cerithium*" *helmerseni*, de Verneuil,[7] judging from the form of the shell with its compressed whorls; but the figure does not indicate an umbilicated base, nor does the description throw light on this point.

1 Bull. Soc. d'Etudes Scientifiques d'Angers, p. 20.

2 Geol. Surv. Minnesota. Palaeontology, 1897, vol. iii., pt. 2, p. 1019.

3 "Guelph Fauna in the State of New York." University State of N. York, 57th Ann. Rep., vol. iii., Mem. 5, 1903, pp. 65 and 67.

4 Mem. Soc. Roy. Sci. Liége, 2nd ser., vol. ii., 1876-7. See also Mem. Geol. Surv. N. S. Wales, Pal. No. 6, 1898, p. 101, pl. iv., fig. 11.

5 Rec. Austr. Mus., vol. i., No. 3, 1890, p. 63, pl. viii., figs. 4, 5; pl. ix., figs. 2, 3. See also Mem. Geol. Surv. N. S. Wales, Pal. No. 6, 1898, p. 101 (footnote).

6 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 129, pl. xii., fig. 18.

7 Geol. de la Russie D'Europe. Murchison, Verneuil and Keyserling, 1845, vol. ii., p. 342, pl. xxii., fig. 4.

In the Lower Devonian of the Karnic Alps, in beds adjacent to Silurian rocks, a *Murchisonia*-like shell has been described and figured by Frech,[1] referred to *Murchisonia davyi*, Barrois, and compared with Lindström's *M. compressa* previously cited. The Lower Devonian fauna of Bohemia is also fairly rich in examples of *Coelocaulus*. In Bassler's "Bibliographic Index of American Ordovician and Silurian Fossils"[2] there are no less than twelve American species listed, seven of which are of Upper Silurian (Niagaran) age, three of Ordovician age, and two of Lower Devonian.

Coelocaulus brazieri, Etheridge fil. (Plate III., Figs. 20-22).

Niso (Vetotuba) brazieri, R. Etheridge, jnr., 1890. Rec. Aust. Mus., vol. I., No. 3, p. 62, pl. VIII., figs. 4, 5; pl. IX., figs. 2, 3. Cresswell, 1894. Proc. R. Soc. Vict., vol VI. (N.S.), p. 158. Chapman, 1907. Rec. Geol. Surv. Vict., vol. II., pt. I., pp. 11, 17.

Description, emended.—Shell turriculate, elongate-conical, slowly tapering to a blunt apex. Apical angle from 25 deg. to 30 deg. Sides gently convexly curved. Whorls about 12 in full-grown examples; surface convex to nearly flat. Sutures fairly well impressed. Slit-band slightly below median line, feebly concave, bounded by raised threads above and below. Traces of spiral threads on the rest of the whorl. Umbilical cavity open from the base to the apex, sides undulating owing to the convex impingement of the whorls on the inner surface. Seen in section the whorls are quadrately globose, and secondary thickening has occurred in some examples, which tend to flatten the external surface of the shell by filling up the suture lines. Length of the largest example about 70 mm., or more when complete.

Observations.—We have already pointed out the relationship of the above and other related forms to *Murchisonia* under the generic heading of *Coelocaulus*. It is interesting to find another species of the same group in Australia, in the Devonian of Yass, viz., *C. darwinii;* thus showing that this peculiar type of shell had as extensive a range as many another Silurian or Devonian genus, and helping to link up the faunas of the two formations.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. From the collection of the Rev. A. W. Cresswell, M.A. Also presented by Mr. J. S. Green and Dr. G. B. Pritchard. In beds of similar age from Marble Creek, Gippsland (Geol. Surv. Vict.—determined by the author).

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1 Zeitschr. d. deutschen geol. Gesellsch., vol. xlvi., pt. iii., 1894, p, 458, pl. xxxii., figs. 4*a-d*.

2 United States National Museum, Bull. No. 92, 1915, p. 249.

Coelocaulus apicalis, sp. nov. (Plate III., Figs. 23, 24).

Description.—Shell somewhat like *C. brazieri*, but spire more acute and with a more numerous apical series of whorls. Apical angle about 25 deg. Whorls depressed convex to flat, short and numerous near the apex, numbering altogether about 20. Sutures well marked, but not widely channelled. Slit-band median or slightly below the median line, depressed in earlier convolutions, prominent in later ones and bordered by raised threads above and below. Umbilical axis open to apex. Cast of perforation more regularly cylindrical than in *C. brazieri*.

Dimensions.—A smaller shell than *C. brazieri*, measuring in the type specimen 40 mm. in length and 16.5 mm. at the base (so far as preserved).

Observations.—The above species appears to occupy a middle position between *Coelocaulus brazieri* and *C. darwinii*. From several examples of the latter species collected by Mr. A. J. Shearsby, one is able to note some interesting points of comparison. It is smaller and more slender in the apical half of the shell than either of the Victorian Silurian species; whilst in the numerous whorls and the cylindrical form of the hollow columella it agrees with *C. apicalis*. The examples of *C. darwinii* from the Shearsby collection came from the Middle Devonian of Yass (Portion 208, Par. Waroo), New South Wales. De Koninck gives the Yass district as the locality, and refers it to the Devonian, whilst Mr. Etheridge refers it to "the Upper Silurian, probably Wenlock, beds of Yass."[1]

Genus **Cyrtostropha**, Donald.

Cyrtostropha lilydalensis, sp. nov. (Plate IV., Figs. 26-28).

Description.—Spire of moderate length, turriculate; consisting of eight whorls, including the protoconch. Sides of whorls convex with the sutures deeply incised. Sinus band median. Growth-lines moderately oblique above and curving backward to the band. and forward below; lines conspicuous on the sinus-band. Band bordered with strong raised lines above and below. Rest of whorl relieved with about three threadlike or slightly nodulose lirae above and below the band. Aperture longer than broad, columellar margin slightly produced. Umbilicus closed.

Dimensions.—Length of holotype (incomplete at base), 31 mm.; width at base about 12 mm. Length of body whorl about 14 mm.

1 Rec. Austr. Mus., vol. i., No. 3, 1890, p. 63.

Width of sinus band on body whorl, 1.25 mm. Length of body whorl of a large specimen about 18 mm.

Observations.—The nearest form to the present species appears to be Sowerby's "*Pleurotoma*" *coralli*,[1] which Miss Donald has placed in the genus *Cyrtostropha*.[2] The British species ranges from the Llandovery to the Ludlow series. The present species differs from the British in the more numerous lirae and their slightly nodulose character. Mr. Etheridge has remarked on a species of *Murchisonia* (sp. ind.)[3] from Lilydale, which from the details given seems to belong to the above form, except for there being no mention of spiral lirae.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill Lilydale. Collected by the Rev. A. W. Cresswell, M.A.

Genus **Goniostropha**, Oehlert.

Goniostropha pritchardi, Etheridge fil. (Plate IV., Fig. 29).

Goniostropha pritchardi, Etheridge, jnr., 1898. Rec. Aust. Mus., vol. III., No. 4, p. 71, pl. XV., figs. 1-4.

Observations.—Some examples of the above species are found in the present collection. They are distinguished from *Cyrtostropha lilydalensis* by the shorter habit and more angulate whorls; the lirate ornament in both forms is very similar, but the sinus band in *C. lilydalensis* is not so deeply excavate.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A.

Genus **Gyrodoma**, R. Etheridge, jnr.

Gyrodoma etheridgei, Cresswell sp.

Eunema etheridgei, Cresswell, 1893. Proc. R. Soc. Vict., vol. V. (N.S.), p. 41, pl. VIII., fig. 2.

Gyrodoma etheridgei, Cresswell sp., R. Etheridge, jnr., 1898. Rec. Aust. Mus., vol. III., No. 4, p. 72, pl. XVI., fig. 1.

Observations.—Mr. Etheridge has referred, in the paper above cited, to the question raised by Mr. Cresswell's depiction of the type specimen as having a double band. An examination of the type, which is in the National Museum collection, shows the band to be single, rather depressed, and marked along the middle with a raised spiral thread; hence the slight mistake in the details of

1 J. C. Sowerby. Sil. Syst., 1839, p. 612, pl. v., fig. 26.
2 Quart. Journ. Geol. Soc., vol. lviii., 1902, p. 322, pl. vii., figs. 5, 6.
3 Rec. Austr. Mus., vol. i., No. 7, 1891, p. 129.

the figure. In the earlier whorls of other specimens the band is distinctly depressed and bounded above and below with a raised thread. The longest example, but imperfect, of this fine species in our collection measures 70 mm.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A., who presented the type specimen.

Fam. EUOMPHALIDAE.

Genus Euomphalus, Sowerby.

Euomphalus centrifugalis, sp. nov. (Plate IV., Figs. 30, 31; Plate VI., Figs. 54, 55).

Description.—Shell compressed, planorbiform. Outline discoidal, but tending to irregular growth; sometimes almost subovate in outline. Superior face gently convex and sloping to the periphery on the last whorl, the inner series excavate; inferior face flat on the periphery and concave towards the centre. Spire visible on both sides and evolute. Aperture compressed, pyriform. Surface of whorls marked by numerous strong, sharply deflected growth-lines.

Dimensions.—Holotype. Greatest diameter, 14 mm.; at right angles, 10.5 mm. Width of last whorl, 4 mm. Approximate thickness of shell, 2.25 mm.

Observations.—This species bears some resemblance to *E. declivis*, Remeles,[1] of the Lower Silurian limestone obtained from the diluvium deposit of North Germany; especially in the sinuate and oblique character of the growth-lines. In that species, however, the whorls are not so deeply concave, and the body whorl tends to become an open spiral.

In general appearance Lindström's *Oriostoma dispar* may be mentioned,[2] which, by the way, is probably a true *Euomphalus* species. In this form, however, the outer whorl is not so highly convex on the inner side nor so steeply sloping to the periphery. Lindström's shell, being a Gotland species, comes from a bed of similar age as the above.

E. centrifugalis appears to be a thin-shelled ancestor of the *Euomphalus catillus* type,[3] a compressed and striate species well known as a Carboniferous limestone fossil.

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1 Zeitschr. d. deutsch. geol. Gesellsch, vol. xl., 1888, p. 669, pl. xxviii., fig. 3.

2 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 173, pl. xxi., figs. 11-14.

3 Min. Conch., vol. 1, 1814, p. 98., pl. xlv., figs. 3, 4. Phillips' Geol. Yorkshire, vol. ii., 1836, pl. xiii., figs. 1, 2.

Occurrence.—Silurian (Yeringian). Apparently fairly common in the newer Silurian. Holotype, in mudstone from Killara, near Seville, Upper Yarra district; presented by Mr. J. S. Green. Paratype, from brown mudstone, Loyola, near Mansfield; presented by Mr. G. Sweet, F.G.S.

Euomphalus northi, Etheridge fil. sp.

Oriostoma northi, R. Etheridge, jnr., 1890. Rec. Aust. Mus., vol. I., No. 3, p. 64, pl. IX., figs. 6, 7.

Euomphalus northi, Eth., fil. sp., Chapman, 1913. Rep. Aust. Assoc. Adv. Sci., vol. XIV., p. 227.

Observations.—The nearly equilateral spiral form of the shell and the concave external face of the umbilicus show the relationship of the above species to be with *Euomphalus*.

The operculum in *Oriostoma* has a convex or conical exterior, whilst in *Euomphalus northi* it is concave.

Examples in the brephic to neanic stages exhibit a smoother shell than the adult form.

Occurrence.—Silurina (Yeringian). Numerous specimens in limestone, Cave Hill, Lilydale. One fine example with the operculum in situ, was presented by the Rev. A. W. Cresswell, M.A.

Genus **Liomphalus**, gen. nov.

Definition.—Shell discoidal, widely umbilicate and biconcave; whorls smooth and sometimes obscurely keeled along the back. Earlier whorls consisting of a thin shelled series, followed by two or more stout whorls, either closely adpressed or free in the later portion. Early part of series divided into chambers as in *Euomphalus* and *Straparollus* (*S. dionysii*, Montf.). Aperture elliptical or angularly ovate. Type, *Liomphalus australis*. The genus includes *Euomphalus disjunctus*, J. Hall, *E.* (*Straparollus*) *clymenioides*, J. Hall, *E. triquetrus*, Lindström, and *E. gotlandicus*, Lindström.

This generic type may be distinguished from *Euomphalus*, Sowerby (*sensu stricto*) in having smooth, rounded or uniangulate whorls; and from *Straparollus*, Montfort, in having a concave spire; whilst from Lytospira, Koken, it differs in the more closely coiled shell, and in the absence of a scaly ornament.

Name derived from *leios*, smooth, and *omphalos*, an umbilicus.

Liomphalus australis, sp. nov. (Plate IV., Figs., 32, 33).

Description.—Shell moderately large, discoid, compressed. Spire somewhat concave, umbilical surface rather deeply concave, consist-

ing of two or three whorls rapidly widening on the last turn, with free surfaces. Exterior smooth. Aperture suboval to subrhomboidal, the angulation when present, situated on or above the median line of the periphery. From the penultimate whorl inwards the shell is divided by deeply concave partitions, the concavity outwards. In some cases the septa are numerous, simulating a cephalopod, but distinguished by the absence of siphuncular openings.

Dimensions.—Greatest diameter of type specimen about 65 mm., when complete. Width of last whorl at 30 mm. from aperture, 16 mm. Length of aperture, 24 mm. Greatest thickness of shell, 13 mm.

Observations.—This species was formerly identified by myself with *Euomphalus disjunctus*, J. Hall,[1] to which species it bears a close resemblance, and it was listed under that name in my paper "On the Palaeontology of the Silurian of Victoria."[2] Upon a closer examination of a fair number of specimens it was seen that the Australian examples were distinct from those of Hall's species from the Upper Pentamerus limestone of New York State, in having a more truly euomphaloid sectional outline to the aperture, which in ours is more angulate, and in the closer coiling of the outer whorls.

In Lindström's *Euomphalus triquetrus*,[3] which I would refer to *Liomphalus*, the outer whorl widens very rapidly, and the aperture becomes everted on the margin, whilst the last quarter turn of the whorl is remarkably free.

In *E. gotlandicus*, Lindström,[4] the shell is closely coiled, and whorls are inflated, with subcircular aperture. The spire in this form is also depressed, otherwise it would naturally fall into the genus *Straparollus*.

Another member of this genus is *Euomphalus (Straparollus) clymeniodes*, J. Hall,[5] from the Devonian of the United States and Canada (Schoharie Grit, New York, and Upper Helderberg limestone, near Cayuga, Ontario). This is a smaller shell than usual, the largest being about two inches in diameter. It has about four or five whorls as in the Australian species, but, unlike it, has them more evenly increasing in diameter, whilst the volutions are not free. The mouth is subovate.

1 Pal. New York, vol. ii., pt. i., 1859, p. 340, pl. lxv., fig. 8; pl. lxvii., figs. 4*a*, *b*.
2 Rep. Austr. Assoc. Adv. Sci., Melbourne Mtg., 1913, vol. xiv., p. 227.
3 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 140, pl. xiii., figs. 32-35.
4 Op. cit., p. 139, pl. xiii., figs. 19-31.
5 Pal. New York, vol. v., pt. ii., 1879, p. 62, pl. xvi., fig. 15; pl. lxx., figs. 1-5.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Chiefly from the collection of the Rev. A. W. Cresswell, M.A.

Genus **Straparollus**, Montfort.

Straparollus debilis, sp. nov. (Plate IV., Fig. 34 ; Plate VI., Fig. 56).

Description.—Shell depressed, subcircular. Whorls about five, rounded, coiled in an irregular spiral and increasing slowly in width. Surface relieved with fine threadlike lines of growth, which are only slightly curved. Aperture subcircular.

Dimensions.—Greatest diameter, about 15 mm.; measurement at right angles about 14 mm. Height of shell, 4.25 mm.

Observations.—This species has a somewhat vermiform appearance from its weakly and irregularly coiled shell. Its nearest specific analogues seem to be *S. rudis*, J. Hall sp.,[1] and *S. hecale*, J. Hall sp.,[2] the former from the Middle Devonian (Hamilton group) of West Bloomfield, New York, the latter from the Upper Devonian (Chemung group) of Rockville, New York. *S. rudis* is a larger shell and increases rather rapidly in its later whorls, whilst *S. hecale* is more regularly discoidal in outline. *S. annulatus*, Phillips sp.,[3] from the Devonian of Newton, Devonshire, is another related form, distinguished by its discoidal outline and prominent growth-lines.

De Koninck has figured a related form to the above from the Silurian at Rock Flat Creek, east side of Maneero, New South Wales, under the name of *Euomphalus solarioides*.[4] This species differs in having an ornament of transverse tubercles instead of striae as in the Victorian species.

Occurrence.—Silurian (Yeringian). In brown mudstone, Ruddock's Quarry, near Lilydale. Collected by F. Chapman.

Fam. TURBINIDAE.

Genus **Omphalotrochus**, Meek.

Omphalotrochus globosum, Schlotheim sp. (Plate IV., Figs. 35, 36).

Trochilites globosus, Schlotheim, 1820. Petrefactenkunde, p. 162

Euomphalus funatus, Sowerby, 1823, Min. Conch., vol. V., p. 71, pl. 450, figs. 1, 2. Id., 1839, Silurian System, p. 626, pl. XII.,

1 *Euomphalus (Straparollus) rudis*, J. Hall. Tom. supra cit., p. 58, pl. xvi., figs. 6, 7.

2 *Euomphalus (Straparollus) hecale*, J. Hall. Ibid., p. 59, pl. xvi., figs. 10-14.

3 *Euomphalus annulatus*, Phillips. Pal. Foss. Cornwall, Devon and W. Somerset, 1841, p. 138, pl. lx., fig. 172.

4 Mem. Geol. Surv. N. S. Wales, Pal. No. 6, 1898, p. 30, pl. i., fig. 5.

fig. 20. Salter, 1867, Siluria, Ed. 4, p. 531, pl. XXV., fig. 3.

Oriostoma globosum, Schl. sp., Lindström, 1884. Kongl. Svenska Vet.-Akad. Handl. Bd. XIX., No. 6, p. 160, pl. XVII., figs. 24, 25, 29-31; pl. XVIII., fig. 24; pl. XX., fig. 16.

Observations.—The representatives in Victoria of this widely distributed species are rare and small. They are clearly referable to the above form on account of the depressed spire, ventricose whorls and expanding mouth. The ornament, as in the European species, consists of numerous spiral keels, about ten on the body whorl, with an intermediate and finer line. The interspaces are crossed by fine and coarse lines rather closely set and slightly curved.

Dimensions.—Greatest diameter of plesiotype, 11 mm.; height, 9 mm. Width of aperture, 7 mm.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A. Also a fine example presented by Mr. J. S. Green.

Fam. TROCHIDAE.

Genus **Scalaetrochus**, Etheridge, jnr.

Scalaetrochus antiquus, Cresswell sp.

Stomatia antiqua, Cresswell, 1893. Proc. R. Soc. Vict., vol. V. (N.S.)., pp. 41, 43, pl. VIII., fig. 3.

Trochus (Scalaetrochus) antiquus, Cressw. sp., Chapman, 1913. Rep. Aust. Assoc. Adv. Sci., vol. XIV., p. 229.

Observations.—Some of the Victorian examples of *Scalaetrochus* appear to indicate the presence of a narrow umbilicus,[1] and therefore show affinity to *Omphalotrochus*.

The above species was founded on a fragmentary shell, which is closely comparable with Etheridge's *Trochus (Scalaetrochus) lindstroemi*.[2] It differs in the slightly convex surface of the volutions, whereas in Etheridge's species they are either flat or concave.

A specimen figured by Lindström from the Silurian of Gotland[3] as *Trochus gotlandicus* shows some affinity with the above, and also with *Sc. lindstroemi*, but it is non-perforate.

De Koninck's *Euomphalus (Omphalotrochus) clarkei*[4] is closely related to *S. antiquus*, and differs only in the stronger and more irregular growth of the shell.

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1 Rec. Austr. Mus., vol. i., No. 3, 1890, p. 66.

2 Ibid., p. 66, pl. viii., figs. 1, 2.

3 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 146, pl. xiv., figs. 1-11.

4 Mem. Geol. Surv. N. S. Wales, Pal. No. 6, 1898, p. 32, pl. i., fig. 7.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. In brown mudstone, junction of the Woori-Yallock and Yarra; Geol. S. Vict. B23.

Scalaetrochus lindstroemi, Etheridge fil. sp.

Trochus (*Scalaetrochus*) *lindstroemi*, R. Etheridge, jnr., 1890 Rec. Aust. Mus., vol. I., No. 3, p. 66, pl. VIII., figs. 1, 2. Chapman, 1913. Rep. Aust. Assoc. Adv. Sci., vol. XIV., p. 228.

Observations.—The high spiral and angulate sutural margins serve to separate this form from *S. antiquus*. It is fairly common in the Lilydale limestone, but has not yet occurred elsewhere, although an indeterminate form of the genus has been noted by me from Yeringian beds at Marble Creek, Gippsland.[1]

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale.

Fam. Trochonematidae.

Genus **Cyclonema**, J. Hall.

Cyclonema lilydalensis, Etheridge fil. (Plate V., Fig. 38).

Cyclonema lilydalensis, Etheridge, jnr., 1891. Rec. Aust. Mus., vol. I., No. 7, p. 128, pl. XIX., fig. 3.

Observations.—In the collection of the National Museum there is a fair number of quite small specimens of *Cyclonema*. As it had been suggested that these probably represent a new species, it is worth putting on record my conclusions regarding them. These small forms consist of about five whorls. The sides of the volutions are rounded, but as a rule the whorls are rather depressed, though occasionally the spire is fairly high, as in *C. australis*.[2] The ornament is exactly similar to that in full-grown specimens of *C. lilydalensis*, and when the number of whorls is taken into consideration, there being from four to six in the small shells, and eight in the fully developed ones, it will be seen that there is no ground for their separation. Further than this, a series of *Cyclonema* in the Dennant collection shows all gradations from the immature to the adult condition. The increase in size of the later whorls is very rapid, the height of a six-whorled shell being 14 mm., and an eight-whorled shell, 42 mm. Mr. Etheridge, in giving the number of whorls as six in *C. australis*, states that *C. lilydalensis* has a much larger number.

1 Rec. Geol. Surv. Vict., vol. ii., pt. i., 1907, pp. 11, 17.

2 Rec. Austr. Mus., vol. i., No. 3, 1890, p. 63, pl. ix., figs. 4, 5.

Occurrence.—Silurian (Yeringian). Cave Hill, Lilydale. Young forms in Rev. A. W. Cresswell collection.

Cyclonema australis, Etheridge fil.

(?) *Cyclonema australis*, R. Etheridge, jnr., 1890. Rec. Aust. Mus., vol. I., No. 3, p. 63, pl. IX., fig. 45.

Cyclonema australis, Idem, 1891, ibid., vol. I., No. 7, p. 127, pl. XIX., figs. 1, 2. Chapman, 1913. Rep. Aust. Assoc. Adv. Sci., vol. XIV., p. 227.

Observations.—This species is separable from *C. lilydalensis* by the stronger liration of the shell-surface, and the more distinct and thread-like ornament crossing the interspaces between the spiral ribs.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Rarer than the preceding species.

Fam. DELPHINULIDAE.

Genus **Craspedostoma**, Lindström.

Craspedostoma lilydalensis, Cresswell sp. (Plate IV., Fig. 37).

Naticopsis lilydalensis, Cresswell, 1893, Proc. R. Soc. Vict., vol. V. (N.S.), p. 44 (name only), pl. IX., fig. 7.

Craspedostoma lilydalensis, Cressw. sp., Chapman, 1913. Rep. Aust. Adv. Sci., vol. XIV., p. 227.

Description of Type.—Shell naticoid, with a short, rather depressed spire of about three whorls and a large body whorl. Whorls inflated and ornamented with an obscure open cancellated structure consisting of flattened spiral and longitudinal ribs. Base umbilicated. In a supplementary specimen a part of the columellar area of the everted lip is preserved, which shows relationship to the above genus.

Dimensions.—Compiled from both examples, and approximate only. Width at base, 27 mm. Height of complete shell, circ., 22 mm.

Observations.—The present species approaches very closely Lindström's Wenlockian form, *C. elegantulum*,[1] in which, however, the ribs are thinner and more conspicuous. In the comparative smoothness of the whorls it shows some relationship also to *C. filistriatum*, Lindström.[2] The genus appears to be restricted to beds of the Upper Silurian epoch.

1 Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 183, pl. ii., fig. 58; pl. xxi., figs. 20-29.

2 Ibid., p. 183, pl. xxi., figs. 35-38.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Collected by the Rev. A. W. Cresswell, M.A.

Fam. PYRAMIDELLIDAE.

Genus **Loxonema**, Phillips.

Loxonema sinuosa, Sowerby sp., var. *australis*, nov. (Plate V., Fig. 39).

? *Terebra sinuosa*, Sowerby, 1839. Silurian System, p. 619, pl. VIII., fig. 15.

Loxonema sinuosa, Sow. sp., Phillips, 1841. Pal. Foss. Cornwall, p. 99, pl. XXXVIII., fig. 182. Salter, 1859, Siluria, 3rd ed., pl. XXIV., fig. 3.

Observations.—The present specimen is fragmentary, only portions of two whorls being preserved. The form of the shell and the ornament is, however, so well indicated as to leave little doubt of its very close affinity to Sowerby's species. The folds are straight and sharply ridged, and the sinuosity well marked, whilst there is a tendency to form a faint nodose shelf near the basal part of the whorl. This latter constitutes a varietal feature.

L. sinuosa has been recorded in Great Britain from the Upper Llandovery beds, the Lower Ludlows and the Aymestry Limestone. Prof. Phillips also recorded it from the Petherwin Group of Cornwall, referred by Jukes-Browne to the Famennian or Upper Devonian.

Occurrence.—Silurian (Yeringian). In limestone, Cave Hill, Lilydale. Presented by Mr. J. S. Green.

Fam. CAPULIDAE.

Genus **Orthonychia**, Barrande.

Orthonychia brevis, sp. nov. (Plate V., Fig. 40).

Description.—Shell conical, slightly curved, less than a quarter of a volution in 12 mm. Convex side of shell evenly rounded, inner surface elliptically convex. Apex compressed and sulcated on the inner side. Lines of growth faintly marked.

Dimensions.—Length of shell about 38 mm. Width of aperture when complete, about 20 mm.

Observations.—A described species which affords a close comparison with the above is *O. subrectum*, J. Hall sp.[1] This shell, however,

1 *Platyceras (Orthonychia) subrectum*, J. Hall. Pal. New York, vol. v., pt. 2, 1879, p. i., pl. i., figs. 1, 2.

is longer and more apically arcuate. It was found in the Upper Helderberg (Lower Devonian) of New York State.

Occurrence.—Silurian (Yeringian). In dark limestone, Loyola, near Mansfield. Collected and presented by Mr. G. Sweet, F.G.S.

Genus **Platyceras**, Conrad.

Platyceras minutum, sp. nov. (Plate V., Fig. 41; Plate VI., Figs. 57, 58).

Description.—Shell minute, consisting of a coiled series of about three whorls. Body whorl rapidly widening. Shell depressed above, gently convex below. Back compressed but rounded. Surface of whorls ornamented with distinct, somewhat salient folds, curving sharply backwards, the interspaces with striated growth-lines. Aperture subangulate, ovoid.

Dimensions.—Greatest diameter of holotype, 4.25 mm. Thickness of paratype, 1.5 mm.

Observations.—This extremely small species resembles the initial portion of a variety of *Platyceras cornutum*, Hisinger sp.,[1] a common Upper Silurian species in Europe. In the holotype the superior face shows the spire to be slightly sunken and evolute. In the paratype, on the inferior face, the spire is involute.

Occurrence.—Silurian (Yeringian). In dark blue limestone, Deep Creek, a tributary of the Thomson River, Gippsland. Collected and presented by the Rev. A. W. Cresswell, M.A.

Platyceras cornutum, Hisinger. (Plate V., Fig. 42).

Observations.—It is practically impossible to specifically separate the many variations of this Silurian type of *Platyceras*, a form which, by the way, also probably extends into the Devonian. It is known from Great Britain, Scandinavia, Germany and the United States. The synonymy is large, and for this Lindström's paper on the Silurian Gasteropoda and Pteropoda of Gotland may be consulted.[2]

The Victorian specimens are of the typical, intermediate form, which is a neritoid shell having a depressed spire. The aperture is broadly ovate, and the growth-lines on the shell well-marked, appearing as irregular concentric folds.

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1 *Pileopsis cornuta.* Lethaea Suecica, 1837, p. 41, pl. xii., fig. 11. *Platyceras cornutum*, His. sp. Lindström, Sil. Gaster. and Pter. of Gotland. Kongl. Svenska Vet.-Akad. Handl., Bd. xix., No. 6, 1884, p. 63, pl. ii., figs. 29-51; pl. iii, figs. 6-9, 19-26.

2 Tom. supra cit., p. 63.

Dimensions.—Two specimens from Loyola measure in greatest length, from outer border of spiral to ventral edge, 46.5 mm. and 30 mm. respectively.

Occurrence.—Silurian (Yeringian). In dark limestone, Loyola, near Mansfield. Collected and presented by Mr. G. Sweet, F.G.S. A small example (cast) in ochreous mudstone. Loyola, near Mansfield; G. Sweet collection.

Platyceras erectum, J. Hall sp. (Plate V., Fig, 43).

Platyceras erectum, Hall, 1879. Pal. New York, vol V., pt. II., p. 5, pl. II., figs. 4-11.

Observations.—The present specimen is a cast in mudstone of a depressed ovate *Platyceras*, partially erect in character and with an open spire. The nearest allied species appears to be J. Hall's *Platyceras erectum*, found in the Lower Devonian of New York State.

Occurrence.—Silurian (Yeringian). In yellow mudstone. Parish of Wallen, Sect. 44; Geol. Surv. Vict. Bb 15.

Genus **Diaphorostoma**, Fischer (= Platyostoma, Conrad, non Klein).

Diaphorostoma retrorugatum, sp. nov. (Plate V., Figs. 44, 45).

Description.—Based on a cast of the thin shell. Consisting of four rapidly increasing compressed whorls, forming a somewhat ovoid outline. Spire slightly elevated. Body whorl large. Base narrowly umbilicate. Aperture apparently suborbicular to ovate. Shell surface traversed by well-marked irregular folds or corrugations which curve obliquely backwards.

Dimensions.—Approximate length of shell when complete, 35 mm. Greatest width, 26.5 mm. Height, 21 mm.

Observations.—This shell appears to be quite distinct from any figured species hitherto known, but approaches *Diaphorostoma lineatum*, J. Hall sp.[1] in general form. That species occurs in the Upper Helderberg limestone of New York, and in the Hamilton Group of the western part of the State.

The Victorian species is distinguished from *Platyceras* by the large and open body whorl.

Occurrence.—Silurian (Yeringian). A cast in yellow mudstone. Ruddock's Quarry, near Lilydale. Collected by Mr. R. H. Annear.

1 *Platyostoma lineatum*, J. Hall. Pal. New York, vol. v., pt. ii., 1879, p. 21, pl. x., figs. 1-21.

Diaphorostoma incisum, sp. nov. (Plate V., Fig. 46; Plate VI., Fig. 59).

Description.—Shell depressed, helicoid; spire moderately depressed, rapidly widening to body whorl, of four volutions. Penultimate whorl one-third the diameter of the body whorl. Surface of shell gently convex, marked with numerous closely set, incised growth-lines, which are sometimes undulate and crossed by sparse, radiating folds. Aperture large, subovate.

Dimensions.—Extreme width, circ., 40 mm. Height, 18 mm.

Observations—In general character the above species approaches *D. lineatum*, J. Hall sp., the fossil cited in the comparison of *D. retrorugatum*, but in that species the body whorl does not increase so rapidly in width, and the shell is higher. The concentric ornament also, whilst agreeing in its incised character, is not crossed by so regular a system of radial lines.

Whidborne's "*Capulus ? invictus*"[1] from the Middle Devonian of Devonshire, is almost identical in form with the Victorian species, but the apical spire is smaller or more closely coiled.

Occurrence.—Silurian (Yeringian). In dark limestone, Thomson River, Gippsland. Collected by the Dept. of Mines, Victoria. No. 91F.

Fam. ? SIPHONARIIDAE.

Genus **Hercynella,** Kayser, 1878.

Hercynella victoriae, sp. nov. (Plate V., Figs. 47, 48).

Description.—Shell patelliform, depressed conical, with a sharp apex. Slopes of shell alternately convexly and concavely folded; one side, on the longer axis, is pinched up to form a subangulate ridge extending to the apex. Concentric lines of growth appearing as low folds. Surface of shell radiately marked with close, low riblets, strengthening as they approach the ventral margin.

Dimensions.—Greatest length of holotype, 53 mm. Greatest width, 35 mm. Approximate length, complete, 55 mm.; width, 39 mm. Height 13.5 mm.

Observations.—This interesting species resembles *H. radians*, Barrande sp.[2] in the radial ornament, but is more elongate-ovate in outline, and the vellication or pinching up of the dorsum is more

1 Pal. Soc. Mon., vol. xliv., 1891. Mon. Dev. Fauna S. of England, p. 204, pl. xix., figs. 12-14.

2 Barrande's Syst. Sil. Bohême. Perner, vol. iv., tome i., 1903, pl. xliii., figs. 20, 21; pl. xlviii., figs. 16-24. Tome ii., 1907, pl. cxxi., figs. 15-18.

marked than in the Bohemian species. *H. radians* is found in the Lower Devonian (Stage F of Barrande).

Occurrence.—Silurian (Yeringian). In olive-grey mudstone. Junction of the Woori-Yallock and the Yarra. Collected by the Geol. Surv. Vict. B23.

EXPLANATION OF PLATES.

N.B.—All the photographic figures are enlarged one-sixth over natural size. For exact dimensions, see text.

Plate II.

Fig. 1.—*Helcionopsis nycteis*, Cresswell sp. Side view of holotype. Cave Hill, Lilydale.

,, 2.—*Helcionopsis elegantulum*, sp. nov. Dorsal view of holotype. Cave Hill, Lilydale.

,, 3.—*H. elegantulum*, sp. nov. Side view of holotype.

,, 4.—*Temnodiscus pharetroides*, sp. nov. Lateral view of holotype. Loyola, near Mansfield.

,, 5.—*T. pharetroides*, sp. nov. Back view of holotype.

,, 6.—*Bellerophon fasciatus*, Lindstrom. Side view. Junction of Woori-Yallock and Yarra.

,, 7.—*Bellerophon* aff. *fastigiatus*, Lindström. Umbilical aspect. Kilmore.

,, 8.—*B.* aff. *fastigiatus*, Lindström. Oral aspect of same specimen.

,, 9.—*Bellerophon pisum*, sp. nov. Umbilical aspect of holotype. Cave Hill, Lilydale.

,, 10.—*B. pisum*, sp. nov. Oral aspect of holotype.

,, 11.—*B. pisum*. Dorsal view of holotype.

,, 12.—*Bellerophon cresswelli*, Etheridge fil. Side view of a senile specimen. Cave Hill, Lilydale.

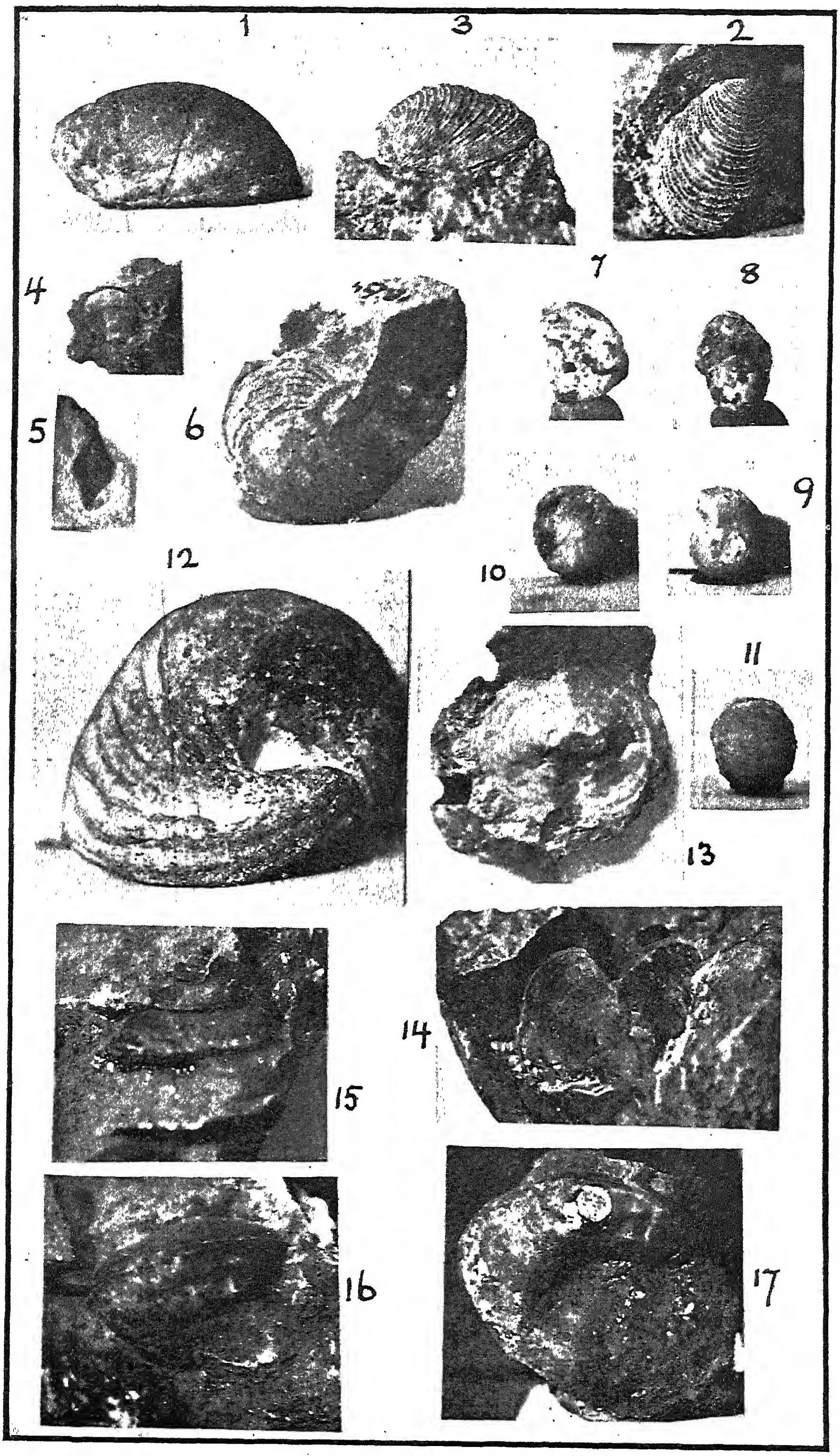
,, 13.—*Carinaropsis victoriae*, sp. nov. Interior of shell of paratype, showing umbonal platform. Ruddock's, near Lilydale.

,, 14.—*C. victoriae*, sp. nov. Exterior of shell, holotype. Ruddock's, near Lilydale.

,, 15.—*Pleurotomaria maccoyi*, sp. nov. Holotype, lateral aspect. Junction of Woori-Yallock and Yarra.

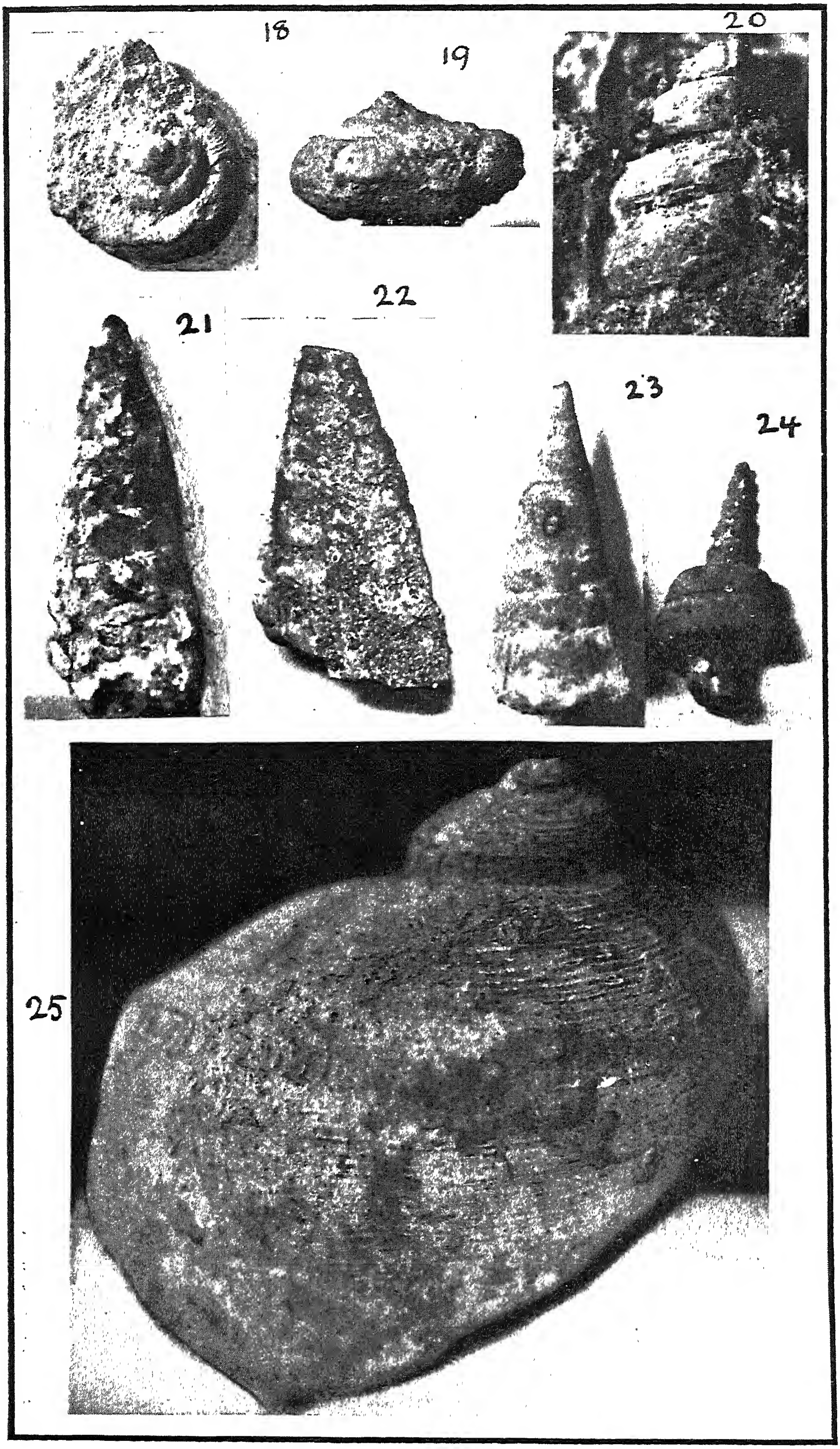
,, 16.—*P. maccoyi*, sp. nov. Paratype. Shell showing slit-band. Junction of Woori-Yallock and Yarra.

,, 17.—*P. maccoyi*, sp. nov. Paratype, showing base of shell. Junction of Woori-Yallock and Yarra.



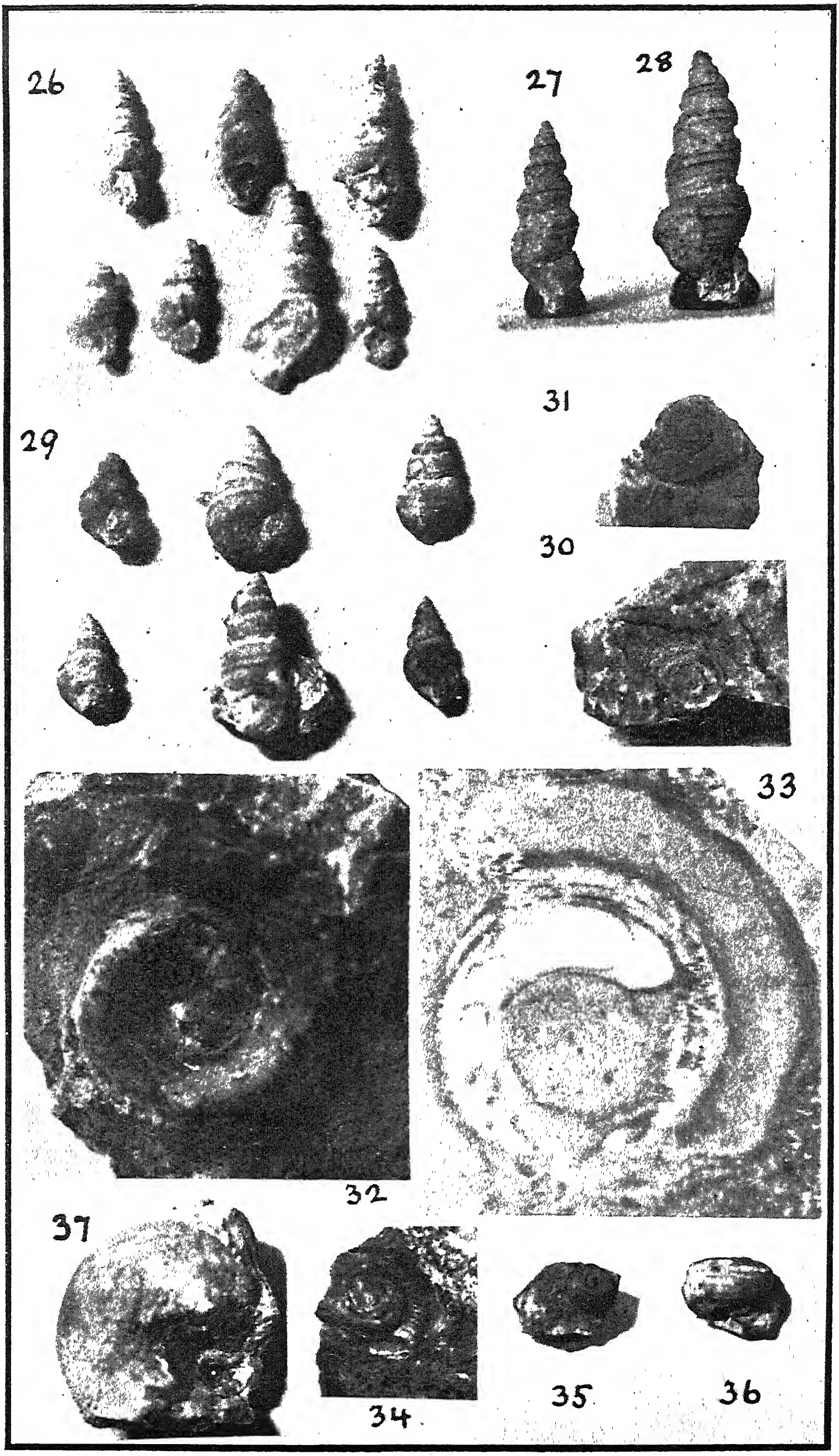
F.C., Photo.

Victorian Yeringian Gasteropods.



F.C., Photo.

Victorian Yeringian Gasteropods.



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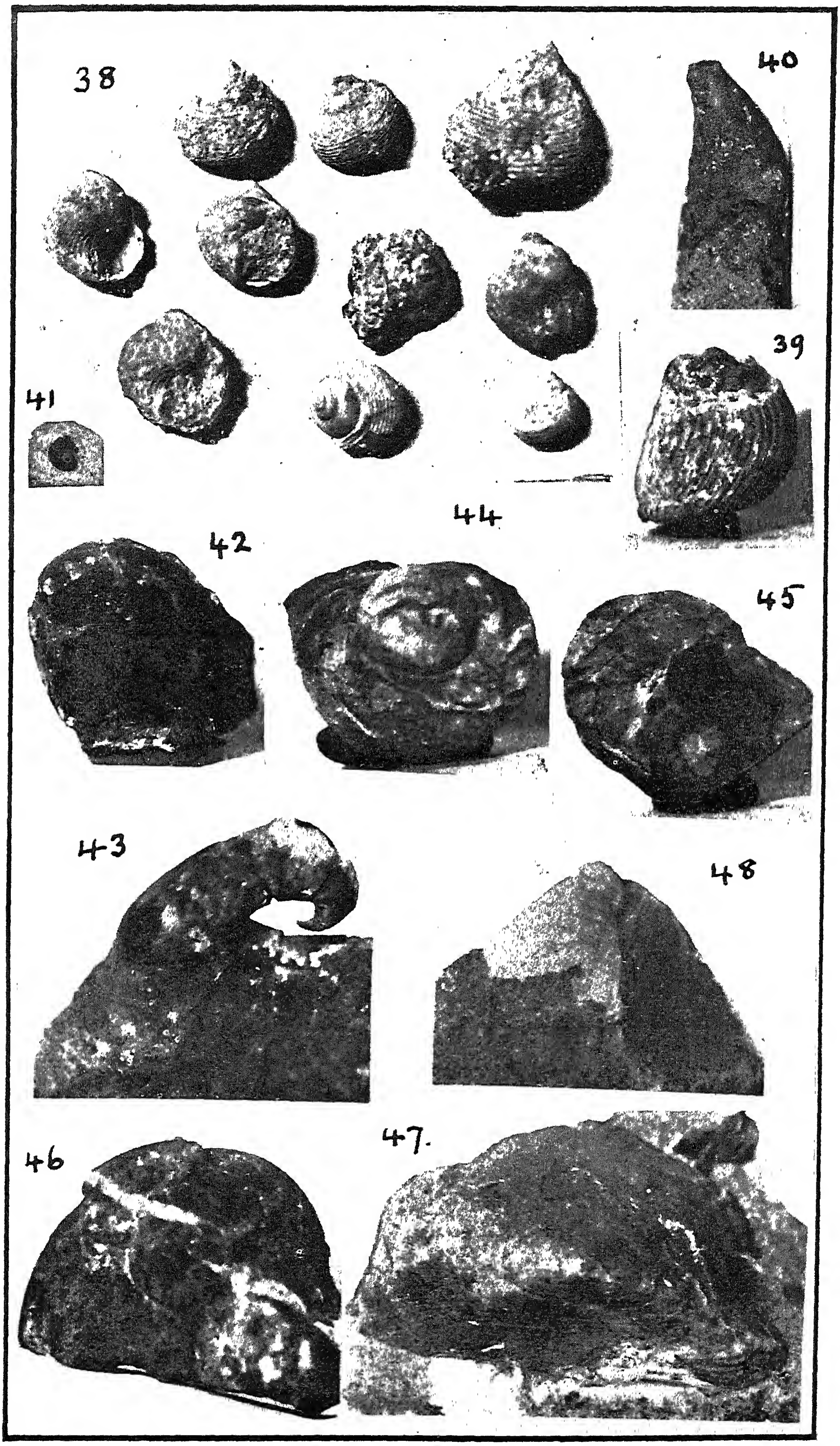
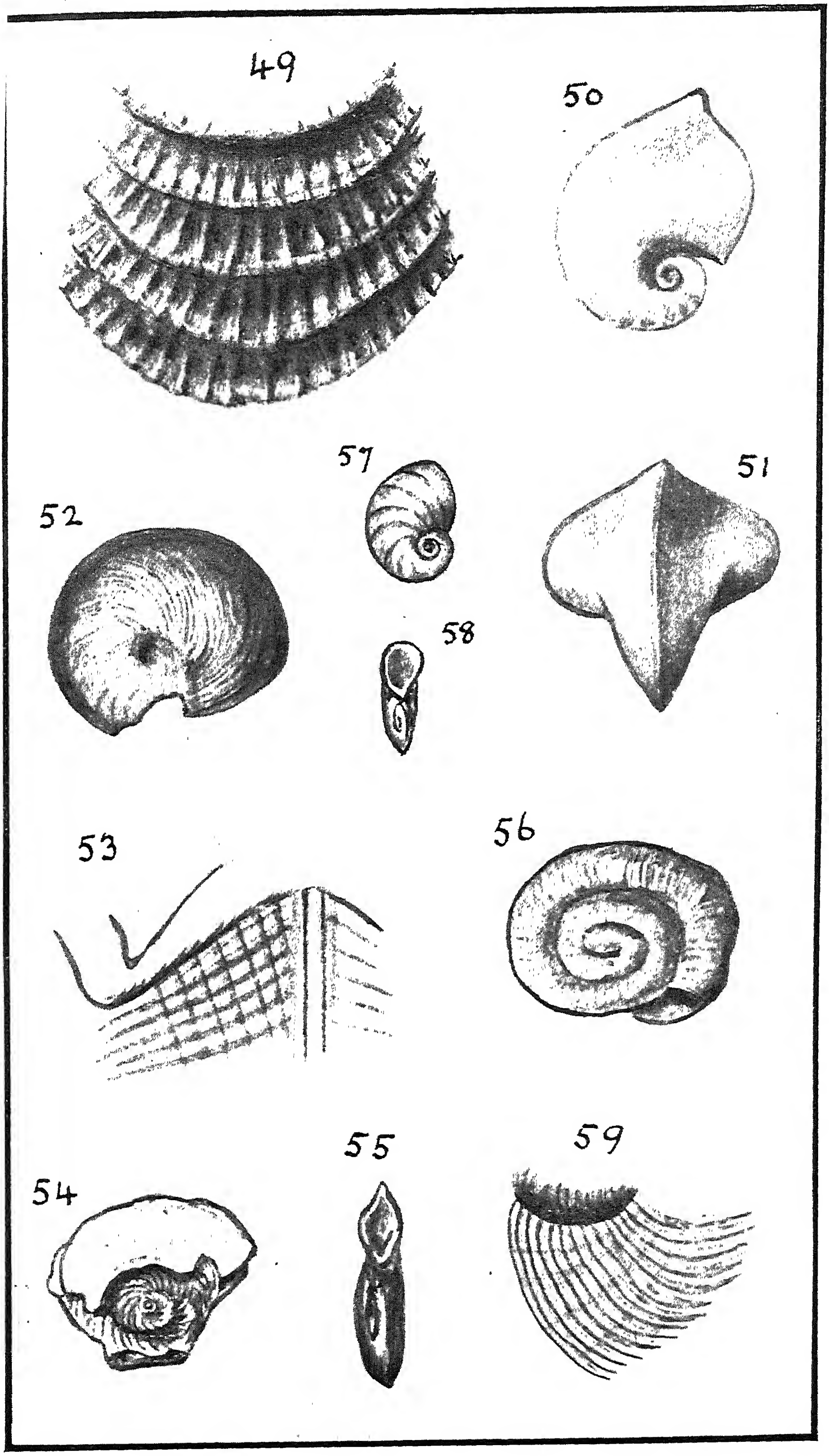
Victorian Yeringian Gasteropods.



F.C., Photo.

Victorian Yeringian Gasteropods.



F.C. ad nat. del.

Victorian Yeringian Gasteropods.

Plate III.

Fig. 18.—*Mourlonia subaequilatera*, sp. nov. Apical view of holotype, Cave Hill, Lilydale.

,, 19.—*M. subaequilatera*, sp. nov. Side view of holotype.

,, 20.—*Coelocaulus brazieri*, Etheridge fil. sp. Basal part of a senile shell, showing slit-band. Cave Hill, Lilydale.

,, 21.—*C. brazieri*, Eth. fil. sp. A typical specimen. Cave Hill, Lilydale.

,, 22.—*C. brazieri*, Eth. fil. sp. Shell sliced through umbilical axis, showing large, persistent canal. Cave Hill, Lilydale.

,, 23.—*Coelocaulus apicalis*, sp. nov. Holotype, showing short conical habit. Cave Hill, Lilydale.

,, 24.—*C. apicalis*, sp. nov. Plesiotype, showing cast of axial canal. Cave Hill, Lilydale.

,, 25.—*Phanerotrema australis*, Etheridge fil. A well preserved specimen, showing large slit-band and ornament on body whorl. Cave Hill, Lilydale.

Plate IV.

Fig. 26.—A group of *Cyrtostropha lilydalensis*, sp. nov. Cave Hill, Lilydale.

,, 27.—*Cyrtostropha lilydalensis*, sp. nov. Paratype, Cave Hill, Lilydale.

,, 28.—*C. lilydalensis*, sp. nov. Holotype. Cave Hill, Lilydale.

,, 29.—A group of *Goniostropha pritchardi*, Etheridge fil. Cave Hill, Lilydale.

,, 30.—*Euomphalus centrifugalis*, sp. nov. Paratype. Killara, near Seville.

,, 31.—*E. centrifugalis*, sp. nov. Holotype. Loyola, near Mansfield.

,, 32.—*Liomphalus australis*, gen. et sp. nov. Holotype. Cave Hill, Lilydale.

,, 33.—*L. australis*, sp. nov. Median section, showing the open whorls and concamerated shell. Cave Hill, Lilydale.

,, 34.—*Straparollus debilis*, sp. nov. Holotype. Ruddock's, near Lilydale.

,, 35.—*Omphalotrochus globosum*, Schlotheim sp. Cast of shell. Cave Hill, Lilydale.

,, 36.—*O. globosum*, Schl. sp. A well-preserved shell. Cave Hill, Lilydale.

Fig. 37.—*Craspedostoma lilydalensis*, Cresswell sp. Umbilical aspect of plesiotype. Cave Hill, Lilydale.

PLATE V.

Fig. 38.—*Cyclonema lilydalensis*, Etheridge fil. A group of young shells. Cave Hill, Lilydale

,, 39.—*Loxonema sinuosa*, Sowerby, var. australis, var. nov. Whorl of shell showing varietal character of ornament. Cave Hill, Lilydale.

,, 40.—*Orthonychia brevis*, sp. nov. Lateral aspect of holotype. Loyola, near Mansfield.

,, 41.—*Platyceras minutum*, sp. nov. Paratype. Deep Creek, Thomson River, Gippsland.

,, 42.—*Platyceras cornutum*, Hisinger. Loyola, near Mansfield.

,, 43.—*Platyceras erectum*, J. Hall sp. Kilmore.

,, 44.—*Diaphorostoma retrorugatum*, sp. nov. Apical aspect of holotype. Ruddock's, near Lilydale.

,, 45.—*D. retrorugatum*, sp. nov. Umbilical aspect of holotype.

,, 46.—*Diaphorostoma incisum*, sp. nov. Apical aspect of holotype. Thomson River, Gippsland.

,, 47.—*Hercynella victoriae*, sp. nov. Apical aspect of holotype. Junction of Woori-Yallock and Yarra.

,, 48.—*H. victoriae*, sp. nov. Lateral view of a crushed specimen. Paratype, showing radial ornament. Junction of Woori-Yallock and Yarra.

PLATE VI.

Fig. 49.—*Helcionopsis elegantulum*, sp. nov. Enlarged ornament from median dorsal area. × 10.

,, 50.—*Temnodiscus pharetroides*, sp. nov. Holotype enlarged. Lateral aspect. × 4.

,, 51.—*T. pharetroides*, sp. nov. Holotype enlarged. Dorsal aspect. × 4.

,, 52.—*Bellerophon fasciatus*, Lindström. Plesiotype, showing growth-lines. × 3.

,, 53.—*Bellerophon cresswelli*, Eth. fil. Portion of surface of senile example, below aperture; showing character of decussate ornament, somewhat restored. × 2.

,, 54.—*Euomphalus centrifugalis*, sp. nov. Holotype enlarged. Lateral aspect. × 2.

Fig. 55.—*E. centrifugalis*, sp. nov. Holotype enlarged. Peripheral aspect. × 2.

,, 56.—*Straparollus debilis*, sp. nov. Holotype enlarged. Lateral aspect. × 2.

,, 57.—*Platyceras minutum*, sp. nov. Holotype enlarged. Lateral (apical) aspect. × 4.

,, 58.—*P. minutum*, sp. nov. Paratype enlarged. Peripheral aspect. × 4.

,, 59.—*Diaphorostoma incisum*, sp. nov. Holotype. Magnified view of ornament on body whorl. × 3.

CORRIGENDUM.

In part XVIII., of this series, vol. XXVIII., pt. I., 1915, p. 158, line 2 from bottom, for 1834, read 1843.

[PROC. ROY. SOC. VICTORIA, 29 (N.S.), PT. I., 1916].

ART. VI.—*Description of a New Genus and two New Species of Victorian Marine Mollusca.*

BY

J. H. GATLIFF

AND

C. J. GABRIEL.

(With Plate VII.).

[Read 13th July, 1916].

LARINOPSIS, nov. gen.

Shell fragile, turbinate, umbilicate, whorls rapidly increasing in size; peristome continuous, slightly reflexed. With an olivaceous epidermis. Operculum horny, annular, with nucleus intramarginal. The animal is viviparous and marine.

Type of genus: Larina ? turbinata, Gatliff and Gabriel.[1]

The shell was provisionally described as a Larina, a genus erected for the reception of a Moreton Bay (Queensland) form, L. strangei, A. Adams. We asked the question respecting the specimen of the northern type species, obtained in McKenzie River: "Was it obtained at a portion of the river beyond tidal influence?" Mr. C. Hedley states[2] that "The McKenzie flows not into the sea, but into the Fitzroy more than a hundred miles from marine influence," and further adds: "Though destructive criticism of this classification is easy, constructive work of correctly placing the Victorian shell is hard," and suggests the placing of it in the genus Pellilitorina of Pfeffer, which in our opinion possesses quite different characters. He also states: "Somewhat similar features are presented by the Antarctic genera Neoconcha, Smith, and Trichoncha, Smith." These similar features we fail to perceive, and have therefore erected a new genus for our shell.

MARGINELLA PROBLEMATICA, sp. nov. (Pl. VII., Fig. 1).

Shell minute, solid, pyriform, white, semi-transparent, spire completely hidden. Aperture running almost the whole length of

1 Gatliff and Gabriel. Proc. Roy. Soc. Victoria, vol. xxii. (n.s.), 1909, p. 35, pl. 13, figs. 1-6.
2 Hedley. Rec. Austr. Mus., vol. viii., 1912, p. 138.

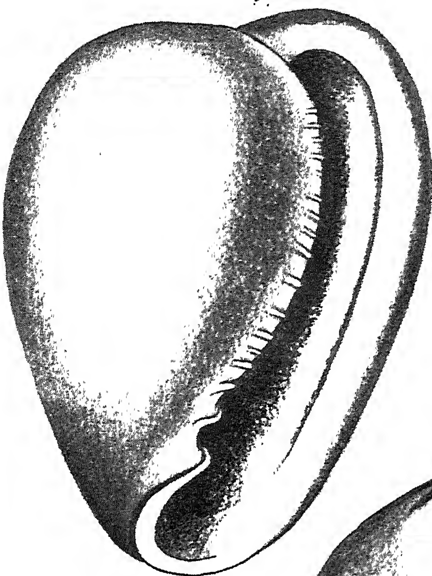


Fig 1

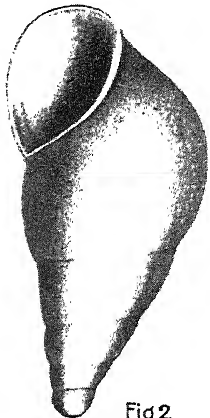


Fig 2

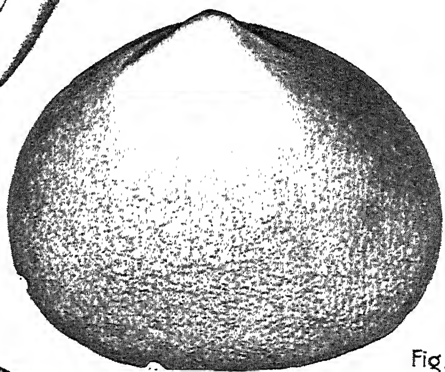


Fig 3

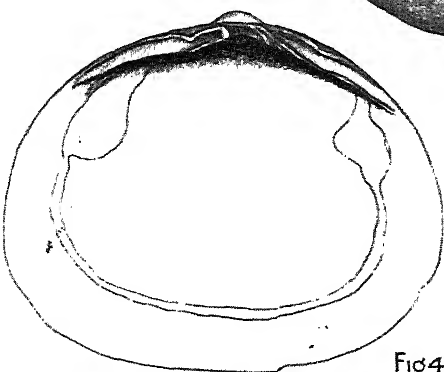


Fig 4

the shell, much curved, with greater width at anterior extremity. Outer lip somewhat thickened, smooth internally, and projecting beyond a slightly flattened summit. Corresponding with the outer lip, the labium is pronouncedly convex, bearing numerous plications, which extend almost the entire length of the aperture, becoming faint posteriorly. The anterior plait is conspicuous and well separated from the remainder.

Dimensions of Type.—Length, 3.50; breadth, 2.50 mm.

Locality.—Dredged Western Port, 8 to 10 fathoms.

Obs.—This strong little species resembles at least two of our Southern Australian forms, *M. halli*, Pritchard and Gatliff, and *M. inaequidens*, May. From the former it is separable by its flattened summit and more triangular shape, and from the latter by its less cylindrical contour, its greater solidity, and in the disposition of the plications, which are stronger in the new species.

Type in Mr. C. J. Gabriel's collection.

LEPTON FRENCHIENSIS, sp. nov. (Pl. VII., Figs. 3 and 4).

Shell thin, creamy white, semi-transparent, quadrately oval, subequilateral. Umboes fairly prominent, projecting slightly beyond the dorsal margin, which is arched. Ventral margin almost straight, while a decided roundness is seen anteriorly and posteriorly. The surface of shell is irregularly, finely, concentrically striated. The valve is sufficiently transparent to discern from the exterior the pallial line, and adductor scars. Hinge normal.

Dimensions of Type.—Anterior-posterior diameter, 3; dorsal-ventral diameter, 2.25 mm.

Locality.—Dredged Western Port, 8 to 10 fathoms.

Obs.—A single valve is selected as type, joined valves not having been taken. The species bears some resemblance to *L. australe*, Angas, firstly, in contour, and, secondly, in lacking the characteristic shagreen sculpture of the genus. The greater depth proportionately, in having more rounded beaks, and the lesser dimensions being the chief points of difference.

Type in Mr. C. J. Gabriel's collection.

EXPLANATION OF PLATE.

Fig. 1.—Marginella problematica, sp. nov.

,, 2.—Eulima immaculata, Pritchard and Gatliff.

,, 3, 4.—Lepton frenchiensis, sp. nov.

The figures are variously magnified.

[PROC. ROY. SOC. VICTORIA, 29 (N.S.), PT. I., 1916].

ART. VII.—*Additions to and Alterations in the Catalogue of the Marine Shells of Victoria.*

BY

J. H. GATLIFF

AND

C. J. GABRIEL.

[Read 13th July, 1916].

In this paper we have added 28 more species to the catalogue, including two new genera, Verticordia and Poroleda. The total number catalogued is now 1080.

The paper includes seven species of the genus Marginella. The Marginellidae of Victoria and Tasmania have hitherto proved a difficult group, but through the close attention bestowed on them by Mr. W. L. May, of Tasmania, many of the difficulties, presented from time to time, have been satisfactorily elucidated. Our work on the group has been greatly facilitated by the gift of numerous typical examples of Mr. May's Tasmanian species. Favoured with this assistance we have been able to critically compare our Victorian forms, and, consequently, augment the list as above. With a record of 38 species, the genus Marginella is well represented in the waters of Victoria.

TURRICULA RETROCURVATA, Verco.

1909. Mitra retrocurvata, Verco. T.R.S., S.A., vol. XXXIII., p. 338, pl. 24, f. 4, 5.

Hab.—In about 40 fathoms, off Ninety Mile Beach.

Obs.—Size of type: Length, 16.5; breadth, 6.25 mm. Quadriplicate.

TURRICULA ACROMIALIS, Hedley.

1915. Mitra acromialis, Hedley. P.L.S., N.S.W., vol. XXXIX. for 1914, p. 730, pl. 84, f. 85.

Hab.—Same as preceding species.

Obs.—Size of type: Length, 9.5; breadth, 4 mm. Quadriplicate.

TURRICULA PUMILIO, May.

1915. Vexillum pumilio, May. P.R.S., Tas., p. 85, pl. 1, f. 5.

Hab.—Same as preceding species.

Obs.—Size of type: Length, 4.3; breadth, 2 mm. Triplicate.

MARGINELLA ANGASI, Brazier.

1870. Marginella angasi, Brazier. Jour. de Conch., vol. XVIII., p. 304, and vol. XIX., 1871, p. 324, pl. 12, f. 3.

1875. Granula angasi, Brazier. Jousseaume, Rev. et Mag. Zool., p. 84.

1883. Marginella angasi, Brazier. Tryon. Man. Conch., vol. V., p. 45, pl. 12, f. 67.

1908. Marginella angasi, Brazier. May, P.R.S., Tas., p. 53.

1915. Marginella angasi, Brazier. Hedley, P.L.S., N.S.W., vol. XXXIX. for 1914, p. 726, pl. 82, f. 66.

Hab.—Portsea, Port Phillip; Western Port; dredged off Wilson's Promontory, and off Ninety Mile Beacth.

Obs.—Size of type: Length, 1.75; breadth, 1 mm. May remarks (*loc. cit.*): "If I have rightly identified the species, then M. halli, Prit. and Gat., is a synonym." His identification is wrong; M. angasi has a slightly elevated spire, in M. halli the spire is totally immersed.

MARGINELLA STILLA, Hedley.

1903. Marginella stilla, Hedley. Mem. Aust. Mus., vol. IV., p. 367, f. 90 (in text).

Hab.—In about 40 fathoms, off Ninety Mile Beach.

Obs.—Size of type: Length, 5; breadth, 2.5 mm. Quadriplicate, lip finely denticulate within.

MARGINELLA SUBAURICULATA, May.

1915. Marginella subauriculata, May. P.R.S., Tas., p. 86, pl. 2, f. 7.

Hab.—Western Port; and dredged off Wilson's Promontory.

Obs.—Size of type: Length, 1.5; breadth, 1.2 mm. Columella with six plaits.

MARGINELLA FREYCINETI, May.

1915. Marginella freycineti, May. Id., f. 9.

Hab.—Dredged off Rhyll, Western Port.

Obs.—Size of type: Length, 2; breadth, 1.2 mm. Triplicate.

MARGINELLA CADUCOCINCTA, May.

1915. Marginella caducocincta, May. Id., p. 88, pl. 2, f. 11.

Hab.—Dredged off Wilson's Promontory.

Obs.—Size of type: Length, 3; breadth. 2 mm. Quadriplicate.

MARGINELLA INCONSPICUA, Sowerby.

1846. Marginella inconspicua, Sowerby. Thes. Conch., vol. I., p. 387, pl. 75, f. 80.

1915. Marginella inconspicua, Sowerby. Hedley, P.L.S., N.S.W., vol. XXXIX., p. 726, pl. 82, f. 64.

Hab.—Dredged off Gabo Island.

Obs.—Size: Length, 5.5; breadth, 3 mm.

MARGINELLA PROBLEMATICA, Gatliff and Gabriel.

1916. Marginella problematica, Gatliff and Gabriel. Antea page 104.

Hab.—Dredged Western Port, in 8 to 10 fathoms.

DAPHNELLA MICROSCOPICA, May.

1915. Taranis microscopica, May. P.R.S., Tas., p. 84, pl. 1, f. 2.

Hab.—Dredged off Wilson's Promontory.

Obs.—Size of type: Length, 1.3; breadth, 0.7 mm. Closely resembling D. excavata, Gatliff.

CASSIS ACHATINA, Lamarck, var STADIALIS, Hedley.

1903. Cassidea turgida, Hedley, not of Reeve. Mem. Aust. Mus., vol. IV., p. 340, pl. 36, f. 1.

1914. Cassidea stadialis, Hedley. Zool., Commonwealth trawler "Endeavour," vol. II., pt. 2, p. 72, pl. 10, f. 4.

Hab.—Dredged in Bass Straits.

Obs.—Size attaining to: Length, 100; breadth, 70 mm. Hedley (*loc. cit.*) states: "Some might regard it as a form of C. pyrum, Lamarck." We consider it to be a large, inflated variety of C. achatina, Lamarck.

EULIMA IMMACULATA, Pritchard and Gatliff. (Pl. VII., Fig. 2).

1900. Stylifer immaculata, Pritchard and Gatliff. P.R.S., Vic., vol. XIII. (N.S.), p. 137, pl. 21, f. 2.

Hab.—Type from Shoreham, Western Port; St. Kilda, and Frankston, Port Phillip; Torquay.

Obs.—Size of type: Length, 3; breadth, 1.5 mm. It was the only specimen obtained at that time, since then we have got others from the localities above indicated, and after critically examining them we have decided to class it as a Eulima. We give another figure of it.

ODOSTOMIA OCCULTIDENS, May.

1915. Odostomia occultidens, May. P.R.S., Tas., p. 90, pl. 4, f. 19.

Hab.—Portsea, Port Phillip; and dredged of Rhyll, Western Port.

Obs.—Size of type: Length, 1.5; breadth, 1 mm. "A very variable species in some particulars."

CERITHIOPSIS DANNEVIGI, Hedley.

1911. Cerithiopsis dannevigi, Hedley. Zool., Commonwealth trawler "Endeavour," pt. I., p. 109, pl. 19, f. 26, 27.

Hab.—San Remo, Western Port; and off Ninety Mile Beach in about 40 fathoms.

Obs.—Size of type: Length, 5.5; breadth, 1 mm.

RISSOA OBELISCUS, May.

1915. Rissoa obeliscus. May. P.R.S., Tas., p. 92, pl. 5, f. 24.

Hab.—Same as preceding species.

Obs.—Size of type: Length, 2.2; breadth, 1 mm. "Smooth and polished."

RISSOA SIMILLIMA, May.

1915. Rissoa simillima, May. Id., p. 93, pl. 5, f. 26.

Hab.—Same as preceding species.

Obs.—Size of type: Length, 1.8; breadth, 1.3 mm.

RISSOA AURANTIOCINCTA, May.

1915. Amphithalamus aurantiocinctus, May. Id., p. 96, pl. 6, f. 33.

Hab.—Dredged off Wilson's Promontory.

Obs.—Size of type: Length, 2.5; breadth, 1.4 mm. A smooth shell of five whorls, with two orange bands on the body whorl.

ACANTHOCHITES LACHRYMOSUS, May and Torr.

1912. Acanthochites lachrymosus, May and Torr. P.R.S., Tas., p. 36, pl. 1, f. 1-4.

Hab.—Torquay.

Obs.—Size of type: Length, 33; breadth, 12 mm. (dried specimen).

CHITON EXOPTANDUS, Bednall.

1897. Chiton exoptandus, Bednall. P. Mal. S., Lond., vol. II., p. 152, pl. 12, f. 7.

1912. Chiton exoptandus, Bednall, Torr. T.R.S., S.A., vol. XXXVI., p. 153.

Hab.—Dredged off Newhaven, Phillip Island, Western Port.

Obs.—Size: Length, 27; breadth, 14 mm. A beautiful Chiton, its principal coloration being red.

TEREDO NAVALIS, Linn.

1767. Teredo navalis, Linn. Syst. Nat. ed. 12, p. 1267.

1915. Teredo navalis, Linn. Gatliff and Gabriel, P.R.S., Vic., Vol. XXVIII. (N.S.), pt. 1, p. 117, pl. XIII., f. 10.

Hab.—Lakes Entrance.

Obs.—This species was discussed by the authors (*loc. cit.*), wherein will be found a list of references.

TEREDO PEDICILLATUS, Quatrefages.

1849. Teredo pedicillatus, Quatrefages. Ann. Nat. Sci., Ser. 3, Zool., vol. II., p. 26, pl. 1, f. 2.

1915. Teredo pedicillatus, Quatrefages. Gatliff and Gabriel, P.R.S., Vic., vol. XXVIII. (N.S.), pt. 1, p. 121, pl. XIII., f. 13.

Hab.—Lakes Entrance; Portsea Pier; Brighton boatslip.

Obs.—The previous observations apply also to this species.

TEREDO BRUGUIERI, Delle Chiaje.

1792. Teredo norvagicus, Spengler. Skriv. Nat. Selsk., vol. II., p. 102, pl. 2, f. 4-6, B (not binomial).

1828. Teredo bruguieri, Delle Chiaje. Memorie., vol. IV., pp. 28 and 32, pl. 54, f. 9-12.

1894. Teredo edax, Hedley. P.L.S., N.S.W., vol. IX., pp. 501-505, pl. 32, f. 1-5.

1903. Nausitora edax, Hedley. Pritchard and Gatliff, P.R.S., Vic., vol. XVI. (N.S.), p. 98.

1915. Teredo bruguieri, Delle Chiaje. Gatliff and Gabriel, P.R.S., Vic., vol. XXVIII. (N.S.), p. 118, pl. XIII., f. 12.

Hab.—Western Port; Lakes Entrance; Portsea Pier; Brighton boat-slip.

Obs.—In their catalogue, Pritchard and Gatliff recorded this species under the appellation of Nausitora edax, Hedley. This is manifestly a synonym of the common European form.

TEREDO FRAGILIS, Tate.

1889. Teredo fragilis, Tate. T.R.S., S.A., vol. XI., p. 60, pl. XI., f. 13a, b, c.

1915. Teredo fragilis, Tate. Gatliff and Gabriel, P.R.S., Vic., vol. XXVIII. (N.S.), p. 122, pl. XIII., f. 14.

Hab.—Brighton boat-slip, and Portsea Pier, Port Phillip.

Obs.—With this addition, five species constitute the representation of the Teredidae in the waters of Victoria. In a communication (these Proceedings, vol. XXVIII., 1915, p. 115, pls. XII.-XIII., figs. 1-4, 6-14), the Teredidae of Victoria were dealt with by the present authors, when it was conclusively shown that T. fragilis, Tate, had erroneously suffered the degradation of a synonym. That such a misunderstanding had occurred is clear from the remarks, and in the figure of the type pallet accompanying it. This is the smallest Victorian form, its nearest ally being T. pedicillatus, Quat. The timber from the first locality was a Eucalypt, in which were associated both forms. The pallets of these species possess distinctive features, which are readily discernible in the figures of above references.

LEPTON FRENCHIENSIS, Gatliff and Gabriel.

1916. Lepton frenchiensis, Gatliff and Gabriel. Antea page 105.

Neolepton novacambrica, Hedley.

1915. Neolepton novacambrica, Hedley. P.L.S., N.S.W., for 1914, vol. XXXIX., p. 701, pl. 79, f. 29-32.

Hab.—Off Ninety Mile Beach, in about 40 fathoms; and off Wilson's Promontory.

Obs.—Size of type: Height, 2; length, 2.2; depth of single valve, 0.6 mm.

Rochefortia anomala, Angas.

1877. Mysella anomala, Angas. P.Z.S., Lond., p. 176, pl. 26, f. 22.

1878. Mysella anomala, Angas. Id., p. 870.

1901. Rochefortia anomala, Angas. Tate and May, P.L.S., N.S.W., vol. XXVI., p. 433.

Hab.—Dredged in eight fathoms, Point Cook, Port Phillip.

Verticordia tasmanica, May.

1915. Verticordia tasmanica, May. P.R S., Tas., p. 99, pl. 8, f. 41.

Hab.—Off Wilson's Promontory.

Obs.—Size of type: Height, 4; width, 4.5 mm.

Carditella vincentensis, Verco.

1908. Carditella vincentensis, Verco. T.R.S., S.A., vol. XXXII., p. 354, pl. 16, f. 20, 21.

Hab.—Off Ninety Mile Beach, in about 40 fathoms.

Obs.—Size of type: Antero-posterior diameter, 3; umbo-ventral, 2.85 mm.

Poroleda spathula, Hedley.

1902. Leda ensicula, Hedley, non Angas. Mem. Aust. Mus., vol. IV., p. 293, f. 41, in text.

1915. Poroleda spathula, Hedley. P.L.S., N.S.W., vol. XXXIX., for 1914, p. 696, pl. 78, f. 17, 18.

Hab.—Off Ninety Mile Beach. in about 40 fathoms.

Obs.—Size of type: Length, 14; height, 4.5 mm. Tate and May correctly stated that Leda lefroyi, Beddome was a synonym of L. ensicula, Angas. Hedley obtained a new species (P. spathula, *loc. cit.*) off Port Kembla, wrongly identified it as being L. ensicula, Angas, and distributed it as such, and stated in the reference first

above cited that Tate and May had been mistaken in their identification; he now admits his error.

MODIOLARIA RADIANS, Suter.

1908. Dacrydium radians, Suter. T.N.Z.I., vol. XL., p. 355, pl. 27, f. 11.
1913. Dacrydium radians, Suter. Man. N.Z. Moll., p. 872, pl. 51, f. 19a.
1912. Modiolaria rhyllensis, Gatliff and Gabriel. P.R.S., Vic., vol. XXV. (N.S.), p. 167, pl. 9, f. 9, 10.

Hab.—Dredged living, off Rhyll, Western Port, in about six fathoms.

Obs.—From a specimen kindly sent to us by Mr. Suter, we are led to the conclusion that M. rhyllensis is the same as his species, but we prefer to class it as a Modiolaria.

END OF VOLUME XXIX., PART I.

[PUBLISHED OCTOBER, 1916.]

[Proc. Roy. Soc. Victoria 29 (N.S.), Part II., 1916].

Art. VIII.—*Oscillatory Adjustments in the Animal Body.*

By W. A. OSBORNE, M.B., D.Sc.
(Professor of Physiology in Melbourne University).

[Read 22nd September, 1916.]

Ostwald has pointed out that if any system be self-adjusting the equilibrium attained must necessarily be oscillatory. As an illustration of this, he cites the thermostat, where the regulator shuts off the heat supply when a certain standard temperature has been exceeded. The result of this withdrawal is a fall of temperature below the desired level; to be succeeded by a rise and so forth. The better the regulating mechanism the smaller are the oscillations, and the best device is that in which the amplitude of the variation is reduced to a negligible quantity. As Ostwald points out, this principle can be extended to human affairs; in politics, for instance, there is always the tendency for opinion to oscillate between radical and conservative positions; in the realm of the aesthetic standards of taste move to and fro between the florid and the austere. I purpose to apply this principle to some aspects of animal physiology, for in the animal body we find numerous adjustments which are relatively constant, and which maintain constancy by self-regulating mechanisms. Amongst the many physiological landmarks in evolution the transformation of a variable into an invariable (temperature, osmotic pressure, etc.) has been conspicuous, but we are compelled to assume that, however close to a fixed standard the adjustment is made, if a self-regulating mechanism is at work a state of oscillatory equilibrium has been established. A number of instances may now be discussed.

I. Respiration.—We owe to Haldane[1] and his school the discovery of the chemical regulation of pulmonary ventilation. If metabolism is not too active as it is in violent exercise there is a remarkable constancy shown in the CO_2 tension of the alveolar air. This means a similar constancy in the tension of CO_2 in the arterial blood, and the standard attained is just that which is adequate to excite the respiratory centre in the medulla oblongata. It does not affect the argument if we hold that CO_2 is the specific excitant, or whether it is the hydrogen ion which is causative. Now, in health, the oscillations above and below the mean of quiet respiration are so damped that they escape recognition (though it is just possible that

1 The Regulation of the Lung Ventilation. J. Physiol., vol. 32, p. 225, 1904.

yawning may find a partial explanation here), but in disease, as Haldane pointed out later, the oscillations may become large and obvious, producing the Cheyne-Stokes breathing, which is so striking a clinical sign. Here we find conformity to the rule that an inadequate or deranged regulator will be made manifest by an increase in the amplitude of the oscillation.

II. Body Temperature.—A great advance in evolution was the rise of the homoiothermal bird and mammal. In poikilothermal creatures metabolism is a function of the air temperature, and comes almost to a standstill in the winter of certain climates. A poikilothermal man could not make definite plans or enter into definite contracts for the performance of work except in the tropics as the ability to labour would rise and fall as the air was warm or cold. Now the temperature of a bird or mammal is not absolutely constant. Vigorous muscular movement, as is well known, may, even in an English winter, drive the temperature up to fever pitch; normality is resumed quickly if the air is cold, slowly if the air is hot and humid. The temperature chart of a healthy human being is by no means a straight line. Even when metabolism is kept fairly constant, as when the subject of the experiment remains fasting in bed, a marked diurnal oscillation is apparent, which may have an amplitude of as much as 0.8°C.[1] Whether this oscillation is that due to self-regulation or is more properly a periodicity effect, is, however, not very clear. Much more likely to be the oscillations in question are those small irregular waves displayed when thermo-electric records are graphically taken. Again, we find that a deranged mechanism will produce an exaggerated amplitude of rhythm. In convalescence from an illness, particularly an illness accompanied by fever, exertion that would not in health affect the adjustment, is sufficient to provoke a decided elevation of temperature, and lead to copious sweating, which, in its turn, can very easily produce subnormality when the exercise ceases.

III. The Muscular System.—It will be evident that if the position assumed by a limb is one extreme of movement, if, for instance, extension be carried as far as the ligaments on the flexor side will allow, the fixation here is mechanical, and no oscillation need be expected. In reflex postural contraction it is also probable that an arhythmical fixation is present for the tension may here be purely elastic, the contractile substance being fixed by a hook mechanism (Grützner)[2], or through gel formation (Sherrington)[3].

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1 See article Die Wärmeökonomie des Körpers, by R. Tigerstedt in Nagel's Handbuch.

2 See Bayliss, Principles of General Physiology, 1915, p. 534.

3 Postural Activity of Muscle and Nerve. Brain, 1915, vol. 37, p. 191.

But when a limb assumes a special directive position through voluntary muscular action there is no rigid attachment, and the constancy of the direction must of necessity be adjusted by the proprioceptive system reinforced by vision or touch, or occasionally by the proprioceptive system alone. Here it is impossible that oscillation could be avoided, and oscillation is assuredly found. Moreover the better the mechanisms involved—the steadier the nerves in popular parlance—the smaller and more uniform are the oscillations. This is well displayed in rifle shooting, particularly when the barrel is unsupported. A good shot is aware of the tremor but he is able to keep it regular and of small dimensions. Similarly in all skilled actions, and skill will always mean precision of spatial and temporal relations, a high degree of efficiency is only possible if the oscillations arising from the adjusting mechanism remain small. Equilibrists and wire-walkers are definitely aware of the oscillatory effect, and consciously resort to fine rhythmic movement to keep the centre of gravity not statically above the small base of support but moving to and fro on either side. Excitement, self-consciousness, lack of experience, strain, fatigue, etc., may in the healthy body produce an extensive increase in the range of oscillation, whilst that exaggeration due to alcoholism, cerebellar disease, senility, neurasthenia, etc., is well known. A small amount of swaying of the upright body when the eyes are shut has often been observed in health, but a marked oscillatory movement has a high diagnostic value. The position of the eyeball is maintained by muscular contraction, guided by macular vision and the proprioceptive information sent up from the eyes muscles. But when a static object is regarded steadily the visual axis is not immobile; there is a slight range of tremor. That this delicate oscillation plays some part in art, especially pointilistic art, has been suggested by H. G. Keller and J. J. R. Macleod[1]. Again, it is possible that in nystagmus we may find the pathological amplification of a normal rhythm[2]. That a voluntary fixation of a limb (using the term limb in its widest sense) must of necessity be oscillatory is not usually assumed in physiological literature, yet a little consideration will show that this must exist. In dealing, therefore, with the rhythm of neural discharge from the central nervous system to the muscles, two possible causes must be borne in mind. There may be an intrinsic periodicity in the nerve cell or nerve cell complex—*i.e.*, rhythmic discharge of each nerve cell or rhythm due to sequence of

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1 Popular Science Monthly. November, 1913.

2 This has been stated precisely by Coppez. Archives d'Ophthalmologie, vol. 33, p. 545.

one nerve cell discharging after the other. This is the causative factor usually assumed. But the rhythm due to absence of mechanical fixation and absolutely necessitated by the adjustments based on sensory impressions is left out of count.

IV. The Blood Constants.—The blood of the higher animals displays remarkable constancy in a number of its characters. Determinations of hydrogen ion concentration have shown that the range of reaction, despite almost gross variations in the reaction of food and of metabolites, is exceedingly small. Here the kidney and lungs are the organs entrusted with the standardisation, or, at least, with the fine adjustment of the standardisation. There is similarly a constancy with respect to osmotic pressure, metallic balance and water content, and again the kidney is the regulating organ. If an oscillation in any of these properties were sought for it would be in the blood from the renal vein, but one might well expect the oscillations to be so small and so damped that they would escape detection. Yet it is surely possible that pathological conditions might exist which would magnify such oscillations and make them detectable and of import to the functioning of the tissues of the body generally.

Arteriolar vaso-constriction is a local variable adjusted to the varying action of gravity on each part of the body and to the varying call for blood from the organs as they are severally excited. Yet there is a mean blood pressure and self-regulating devices, such as the depressor nerve or the direct action of high pressure on the medulla, have been proved to exist. Though once more the oscillations produced may be too small and too damped to be made manifest, it is again possible to assume that they may be greatly exaggerated in pathological states.

What determines the total quantity of blood in the body, the concentration of plasma proteins, and the number of formed elements, physiology as yet has not determined, but if self-regulating mechanisms are at work, the same argument applies.

The above are a few only of the self-adjusting processes in the body. There are many others not touched upon. One has only to think of the reflex excitation of the lachrymal gland, which is so finely-adjusted that both dryness and excessive moisture of the cornea are avoided, of the secretion of mucous surfaces, of the growth of the skin *pari-passu* with frictional loss and such like, to realise that self-adjustment is the rule and not the exception. And in all self-adjusting systems, we may venture to state, rhythm, if not apparent, is latent, and can be brought into prominence by pathological changes.

[PROC. ROY. SOC. VICTORIA 29 (N.S.), PART II., 1916].

ART. IX.—*The Wet-Bulb and Kata Thermometers.*

BY W. A. OSBORNE, M.B., D.Sc.
(Professor of Physiology in Melbourne University).

[Read 22nd September, 1916.]

The ordinary thermometer which records the temperature of its immediate environment, is, as is now well known, an unreliable guide to those air conditions that influence the animal body. "It affords no measure of the rate of cooling of the human body, and is, therefore, a very indifferent instrument for indicating atmospheric conditions which are comfortable and healthy to man."[1] Of the three air factors for which the body has to make adjustments in order to keep thermostatic—namely, the temperature, water content and velocity, the thermometer records one only. The great superiority of the wet-bulb reading over the dry-bulb reading consists in this that the wet-bulb does respond to all these three variables. Though Harrington pointed out the importance of wet-bulb records, naming their indications "sensible temperatures," and actually mapped out the United States of America in wet-bulb isotherms for the month of July,[2] yet it is to Haldane[3] that we are chiefly indebted for pointing out the importance of this instrument. Haldane made some interesting recommendations concerning wet-bulb standards of temperature in mines and factories. He also pointed out that there is for the human being a critical wet-bulb temperature where the conditions are such that the body, even at rest, cannot lose its heat quick enough, and cumulative fever results. This has been confirmed by other investigators, and I may add that I have had opportunity to put the matter to the test with results that agree with Haldane's conclusions. The first great extension of the use of the wet-bulb in climatology occurred here in Australia when the Commonwealth Bureau of Meteorology, under Mr. H. A. Hunt, published maps giving wet-bulb isotherms in Australia for each month of the year 1910. After this a systematised series of wet-bulb observations was undertaken giving records of temperature in homes, offices, etc., as well as outside shade in Northern Territory, and the tropical parts of Queensland. I have had access to these records

1 Leonard Hill, O. W. Griffith and Martin Flack, The Measurement of the Rate of Heat Loss, etc. Phil. Trans. B, vol. 207, p. 184.

2 Quoted in Hann's Handbuch der Klimatologie, 1908, vol. i., p. 57.

3 J. S. Haldane. Journal of Hygiene, 1905, vol. 5, p. 494.

through the courtesy of Mr. Hunt, and find most interesting material contained in them, though to make adequate use of such data would demand more time than I am able to bestow.

The estimation of one's state of discomfort in hot weather is obviously impossible to carry out with any approach to exactness. I have tried various expedients but without result. The amount of sweat absorbed by the clothes is no guide at all, for, in this climate in summer, we have days when the human body may lose over 400 grammes[1] water per hour by evaporation and yet the skin and clothes remain dry and comfort is not greatly disturbed. A rough and ready indication which I have come to regard as the most useful is simply the clothing that is chosen as the most comfortable when the body lies in an open-meshed hammock in a good shade and at perfect rest. If such a hammock is not at hand, the upright position is, I think, best, and much preferable to resting in, say, a deck chair.[2] Judged roughly in this way, and by general feeling, I have placed wet-bulb 73° F. as an empiric standard above which truly tropical conditions arise. This wet-bulb temperature is seldom attained in the Victorian climate. A typical instance of the effect of dryness in keeping the wet-bulb down is shown in the following :—

Place.	Time.	Dry-Bulb F.	Wet-Bulb F.
Mildura	Dec. 30, 1908, 3 p.m.	110	69

contrast this with

Place.	Time.	Dry-Bulb F.	Wet-Bulb F.
Nottingham	July 29, 1911, 1 p.m.	82	73.6
Kew, London	July 29, 1911, 3 p.m.	87.7	71.3

The last-mentioned high temperature I experienced personally and can truthfully say that it exceeded in unpleasantness anything that I have felt in Melbourne or its environs.

The wet-bulb isotherms drawn by Mr. Hunt show very clearly that of all portions of Australia the worst from the climatic standpoint is the pearling coast in the north-west. In December, January and February this district is included within the 80° W.B. isotherm. I find that on December 24th, 1909, the shade wet-bulb temperature at Wyndham on this coast was 85° F. at 9 a.m. !

1 W. A. Osborne. Contributions to Physiological Climatology, Part II. J. Physiol., vol. 49, p. 133.

2 I have made some measurements of the water loss of the body in two almost successive hours in practically the same meteorological conditions, the first hour in a hammock, the second in a deck chair, and found that in the latter case the water loss was considerably increased in each instance owing to the impeded evaporation—the water given off by the skin was of course to be found in the fabric of the deck chair and in the clothing with which it was in contact.

In the course of observations, I began to detect some discrepancies between the wet-bulb reading and the state of discomfort of the body. The most striking of these occurs when a hot day with strong north wind and clear sky undergoes a "change." The sky becomes overcast and the wind drops. There may or may not be electrical disturbance. At this time the air conditions may become most oppressive, and sweating may be very copious on exertion. Now, in all the observations I have made in five summers, I have only noted two occasions in which the wet-bulb rose with the overcasting of the sky and the drop in the wind. In all other cases the wet-bulb, like the dry-bulb, fell. I, therefore, came to the conclusion that the wet-bulb is not sufficiently sensitive to air currents. Experiments on the evaporation from the skin and from an evaporimeter confirmed me in this view.[1] I, therefore, devised a wet-bulb thermometer, having its bulb within a cylindrical gauze cage open at the bottom but otherwise covered with cloth. At the suggestion of Professor Roaf bolting cloth of standard mesh was used for this latter purpose. These "jacketed wet-bulb thermometers" manifested a much better response to air movement, and when tested in a "change," usually gave a rise in temperature. Further experience, however, brought to the light new difficulties. The cloth was apt to get greasy, and to shrink, so I fell back on various porous substances. The same trouble with grease still pursued me, and, most annoying of all, I found that the slightest shift in the position of the bulb made a change in the height of the column, and that it was practically impossible to obtain two jacketed thermometers that gave the same reading. This particular effort, then, which has cost me some considerable time I have been compelled to give up, as I do not see how standardisation can be effected.

The Kata-thermometer of Leonard Hill works on a different principle. Here the time of cooling of a large wet-bulb through a range of 10° F. (from 100° F. to 90° F.) is taken, and the cooling power of the air calculated in terms of millicalories per cm^2 per second. I have had just one summer's experience with three of these instruments, one of them having been kindly sent to me by Professor Leonard Hill who had worked out its special factor.[2] The Kata-thermometer certainly indicates well the onset of oppressive thunder weather and therein manifests its superiority to the wet-bulb. But I soon discovered that in its present form it is somewhat too sensitive to air currents, at any rate in hot, dry weather. The following

1 W. A. Osborne. Contributions to Physiological Climatology, loc. cit.

2 A kerosene tin can be employed with very fair results for obtaining the reading in still air.

data, expressed in seconds, for the cooling of a wet Kata from 100° F. to 90° F., may be taken as illustrating this. Date—Dec. 28th, 1915.

Time.	Dry-Bulb F.	Wet-Bulb F.	Kata Time.	Wind.
0–20 p.m.	94.3	68.7	38″	slight
0–30 p.m.	94.3	68.7	41″	slight
0–35 p.m.	94.5	68.8	43″	very slight
1–45 p.m.	98.7	70	34″	gust

I found, indeed, that it was easy to obtain, especially, as I have said, in hot, dry weather with unsteady wind, greater variations in the wet Kata reading than it was possible that the state of the body could parallel. In fact, theory would suggest that the bulb of the Kata should approximate in size, shape and water equivalent to the human body if correct values are to be obtained. Of course, a series of readings in fairly quick succession could be taken with the present Kata, and the average computed, but this would be tedious. On the other hand, in calm weather, also when the wind was moderately steady, I obtained consistent readings.

More experience is necessary before I can venture to come to a conclusion. Yet, so far as my observations go, I feel that for estimating air conditions in mines and buildings, and possibly sheltered outside places where variations in air velocity are not of much magnitude, the Kata-thermometer is the better instrument. Very probably, too, it could be used profitably in those tropic areas where calm weather is the rule. But for ordinary climatological purposes I still feel that the wet-bulb record is of high value.

[PROC. ROY. SOC. VICTORIA, 29 (N.S.), PART II., 1917].

ART. X.—*On the Probable Environment of the Palaeozoic Genus Hercynella in Victoria.*

BY FREDERICK CHAPMAN, A.L.S., &c.
(Palaeontologist to the National Museum, Melbourne).

[Read November 9th, 1916].

The recent discovery[1] of the interesting gasteropod *Hercynella*, a supposed pulmonate or air-breathing mollusc, in the newer Silurian or Yeringian of the Upper Yarra district in Victoria, leads one to enquire into its mode of living. This enquiry may be conducted on two lines—viz., that of the nature of the sediment in which it occurs, and the other, regarding the fauna with which it is associated.

Before entering upon these questions, it will be well to consider the views of Marjorie O'Connell on this subject[2] in regard to the species of *Hercynella* occurring in the Waterlime Group (=Upper Ludlow) of North Buffalo, U.S.A., at what seems to be an identical horizon as the Victorian, so far as one can judge by associated faunas. Miss O'Connell's note on the "Habitat of Hercynella" (loc. cit. p. 100) is here given in full:—

"The horizon in Bohemia in which the largest number of Hercynellas has been found is F or Upper Monroan [Lower Devonian]. Here they are associated with vast numbers of graptolites, and also with sponges, trilobites and tentaculites. The fauna is undoubtedly marine, and since it is well-preserved, and the Hercynellas are also numerous and in good condition, there is no reason for questioning the marine habitat of the species of Bohemia. Furthermore, the shells are comparatively thick, showing no lack of carbonate of lime for impregnation. The one specimen from the Monroe limestone of Michigan likewise has good marine associates, though its macerated condition and the fact that no other specimens have been found would leave it an open question whether it was a true marine form or merely one swept out to sea by land waters. The Hercynellas which have been found in the Bertie waterlime, seem to indicate conditions other than marine, for their shells are exceedingly thin, as though available lime were not abundant in the water in which they lived, and, moreover, their faunal associates are not typical marine forms, there being only eurypterids, ceratiocarids and the

1 Proc. Roy. Soc. Victoria, vol. xxix., (n.s.), pt. i., 1916, p. 99, pl. v., figs. 47, 48.

2 Bull. Buffalo Soc. Nat. Sci., vol. xi., No. 1, 1914. Description of some New Siluric Gasteropods, pp. 93-101, 1 plate.

plant *Bythotrephis lesquereuxi*, together with a few water-worn specimens of *Orthoceras*. The writer has elsewhere[1] discussed at length the significance of this unique fauna and bionomic conditions which it indicates. The very thin shell of these pulmonate gastropods may be taken as a slight bit of additional evidence to that given in the paper above referred to in support of the view that the Bertie waterlime was deposited not in marine water, but in brackish or fresh water, and that the Hercynellas, as well as eurypterids, were carried into the Bertie muds by the rivers. If, on the other hand, *Hercynella* is to be regarded as a marine genus, then we have here another case of intermingling of marine and fluviatile species in the region of deposition at their junction."

The sediments in which the Yeringian (newer Silurian) fossils are found in the Upper Yarra district are mudstones. This fossil collection was made prior to 1856 by the Geological Survey of Victoria, the locality number being B 23, and the exact position, near Stewart's station, at the junction of the Woori Yallock Creek and the Yarra River. These mudstones are olive-brown in colour, varied with dark grey streaks, and distinctly micaceous. The structure appears to indicate that the rock was either deposited in shallow water or in areas subjected to currents. From the occurrence of corals and gasteropods in this fauna one is inclined to infer that the water was not very shallow, but that periodic incursions of mud took place. That there may also have been a fair amount of decaying matter brought down to this area by streams is evident from the abundance of ostracods (*Beyrichia*), for these little crustaceans probably fed on the drifted weed and similar pabulum.

The following is a list of fossils associated with *Hercynella victoriae* in the mudstone at the junction of the Woori Yallock and the Yarra :—

Coral—
- *Lindstroemia*, sp.

Worm—
- *Trachyderma* cf. *squamosa*, Phillips.

Polyzoan—
- *Fenestella margaritifera*, Chapm.

Brachiopods—
- *Camarotoechia*, sp.
- *Nucleospira australis*, McCoy.
- *Orthis actoniae*, Sow.

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1 Bull. Geol. Soc. America, vol. xxiv., 1913, pp. 499-515.

Strophomena ?antiquata, Sow. sp.
Stropheodonta (Leptostrophia) alata, Chapm.

Bivalves—
Conocardium bellulum, Cresswell sp.
Mytilarca acutirostris, Chapm.
Nuculites maccoyianus, Chapm.
Palaeoneilo raricostae, Chapm.

Gasteropods—
Bellerophon fasciatus, Lindström.
Pleurotomaria maccoyi, Chapm.
Conularia sowerbii, Defr.

Cephalopod—
Orthoceras lineare, Münster sp.

Trilobites—
Lichas australis, McCoy.
Odontopleura jenkinsi, Eth. fil. and Mitch.
Odontopleura rattei, Eth. fil. and Mitch.
Phacops sweeti, Eth. fil. and Mitch.

Ostracods—
Beyrichia kloedeni, McCoy.
Beyrichia kloedeni, var. *granulata*, Jones.
Beyrichia wooriyallockensis, Chapm.
Beyrichia ligatura, Chapm.
Beyrichia maccoyianus, Jones, var. *australiae*, Chapm.

Cirripede—
Turrilepas cf. *yeringiae*, Chapm.

It has been suggested by Miss O'Connell, in the case of the Waterlime Hercynellas that being thin-shelled they probably lived under fresh or brackish-water conditions, and were subsequently swept by rivers into the sea. Our Victorian species is, like the Waterlime fossils, apparently thin in texture, but the perfect condition of the cast of the figured type is so striking as to preclude the idea of its having drifted into the marine mud.

The absence of eurypterids from the Yeringian, and, with one exception, all ceratiocarids, both groups of which are so common in the Waterlime series of North Buffalo, is additional evidence in favour of a marine origin for the Victorian Yeringian deposits. The same cannot be said, however, of the Melbournian sediments, whose fauna contains a *Pterygotus* and numerous ceratiocarids.

That the mudstone of locality B 23 is of marine origin is evident from the fairly large assemblage of brachiopods, bivalves and gasteropods which it contains. The thin-shelled condition, not only of

Hercynella, but of the molluscs and brachiopods occurring in the Victorian Yeringian, seems, therefore, entirely due to the fact that the waters were frequently rendered turbid by the periodic discharge of terrigenous material by rivers, and possibly also by coast erosion, a condition which acts severely on lime-secreting organisms, a fact that can be proved by examining the shore-faunas of land-locked and mud-swept bays at the present time.

The conclusions drawn from the above data are :—

1.—That the Hercynellas of the Victorian Yeringian were of marine habits, as proved by the associated fauna.

2.—That the sediments of locality B 23, in which Hercynella occurs, were laid down under fairly deep-water marine conditions, but the areas of sedimentation may have been periodically subjected to invasions of mud brought down by rivers.

3.—That the lime-secreting fauna of the Yeringian mudstones tends to prove, by the thin shells, that the terrigenous element in the Yeringian sea was so marked as to considerably lower the amount of carbonate of lime available to those organisms.

[Proc. Roy. Soc. Victoria, 29 (N.S.), Part II., 1917].

Art. XI.—*Reptilian Notes:*

Megalania prisca, Owen, and Notiosaurus dentatus, Owen; Lacertilian dermal armour; Opalized remains from Lightning Ridge.

By R. ETHERIDGE, Junr.
(Curator of the Australian Museum, Sydney).

(With Plate VIII.).

[Read November 9th, 1916].

1.—The Identity of Megalania (vel. Varanus) prisca, Owen, with Notiosaurus dentatus, Owen. (Pl. 8, Figs. 1-4).

The late Mr. Richard Lydekker remarked:—" Sir R. Owen has described two peculiar blunt and pleurodont teeth of a large lizard from the Pleistocene of Queensland under the name of *Notiosaurus*, which is, however, preoccupied by the genus *Notosaurus*. . . . It is just possible that the teeth may be referable to *Varanus priscus*, in which event the generic name *Megalania* would have to be retained for that form."[1]

I am now in a position to materially confirm Mr. Lydekker's astute conjecture. The Australian Museum has long been in possession of numerous vertebrae, undoubtedly those of Owen's *Megalania prisca* from fluviatile deposits near Clifton Station, King Creek, Condamine River.

Associated with these, like in appearance, colour, and condition of petrifaction, are a few limb bones, and the larger portion of a right dentary, with part of a tooth *in situ;* there can be no reasonable doubt that these remains all belonged to one and the same species of reptile.

This dentary portion (Pl. 8, figs. 1 and 2) is fractured in front at about the premaxillary suture, and as preserved measures six and a-half inches in length. Posteriorly it is also fractured contiguous to the prefrontal-lachrymal sutures, so that nearly the whole of the bone is preserved. On the external surface (Pl. 8, fig. 1) are visible six large foramina of the maxillary artery branches (anterior branch of external carotid). On the anterior aspect along the alveolar

1 Lydekker. Nicholson's Man. Pal., 3rd Edit., ii., 1889, p. 1142. A suspicion of this appears to have occurred to the late Mr. C. W. de Vis (Proc. Roy. Soc. Queensland, vi., 1890, p. 97).

channel are the concave surfaces of attachment of seven pleurodont teeth (Pl. 8, fig. 2), another with the dental tissue remaining on it, and the base of a ninth, the tooth fractured transversely, and displaying the pulp cavity. At the base of the tooth represented by dental tissue may be seen the foramen leading into the space in which a new successional tooth would be developed.[1]

The dental impressions (Pl. 8, fig. 2) along the alveolar channel average one and three-eighth inches vertically by five-eighths of an inch transversely, but the immediate surface of tooth attachment averages six-eighths by five-eighths. The base of the remaining tooth is longitudinally grooved as in the better of the two figured by Owen as *Notiosaurus dentatus*,[2] indicating the inflected folds of the external cement.

There are six foramina on the exterior of the dentary of the maxillary artery branches, the second in retiring order double, the sixth and last again double, but the two meati are united whilst still exhibiting evidence of a former separation. This posterior "dumb-bell"-shaped foramen enlarges inwards and upwards immediately beneath the lachrymal bone (Pl. 8, fig. 1)..

In the Water Monitor (*Varanus salvator*) these foramina are nine in number. The posterior terminal is simply transversely elongated instead of dumb-bell shaped, and it is the most anterior, instead of the second anterior as in *Megalania*, that is double. In the Australian *V. varius*, Shaw, there are again nine foramina, all single, and the posterior opening as in *V. salvator*.

Notiosaurus dentatus, from Cuddie Springs, New South Wales, it is true, was established[3] by Owen on a mere fragment of the dentary element of a mandibular ramus with portions of two teeth, but the form of these teeth, method of implantation against the alveolar wall, and nature of the cement infoldings are so essentially those of the dentary portion accompanying the *Megalania* vertebrae, that I have no doubt of their identity. I very much doubt if the tooth figured by Mr. de Vis as *Notiosaurus dentatus*[4] is in any way related to Owen's fossil of the same name.

The words of Owen, in describing the dentition of the Crocodilian Monitor (*V. crocodilinus*) apply so well to the present specimen, that I cannot refrain from quoting them. The teeth "are anchylosed by the whole of their base, and by an oblique surface leading up-

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1 Tims. Tomes' Man. Dental Anatomy, 7th Edit., 1914, p. 310.
2 Owen. Phil. Trans., 175, pt. i., pl. 12, fig. 2*b*.
3 Owen. Ibid., p. 249.
4 De Vis. Proc. Roy. Soc. Queensland, ii., 1886, pl. iii., fig. 2.

wards on the outer side of the tooth to a slight depression on the oblique alveolar surface as in *Var. striatus.* . . . The alveolar channel or groove has scarcely any depth; but the anchylosed base of the tooth is applied to an oblique surface, terminating in a sharp edge, from which the outer side of the free crown of the tooth is directly continued."[1]

2.—Megalania prisca, a Cave Fossil. (Pl. 8, Figs. 3 and 4).

A few months ago I received a small consignment of bones from the ossiferous deposit at the Wellington Caves Reserve. For some time past a commercial venture, known as the "New South Wales Phosphate Co. Ltd.," has operated on a portion of the area in question. From vugs, vertical crevices, the latter possibly leading to unexplored cave-chambers, and shaft exploration, a large quantity of ossiferous material in red cave-earth has been extracted.[2] To the courtesy of Mr. George Dixon, of the above company, the Trustees are indebted for a small collection of bones from one or other of these openings.

Amongst the specimens my attention was at once attracted by a large vertebra more or less enclosed in red earth. On being freed from the latter, it was found to correspond in every detail with the dorsal vertebrae forming a portion of the series already referred to from near Clifton Station.

The neural spine (Pl. 8, fig. 3) is broken off immediately above the level of the post-zygopophyses, only the right hand one of which approaches entirety. The pre-zygopophyses are also fractured, the left being the more complete. As compared with Owen's dorsal figure,[3] the pre-zygopophyses are relatively lower in position, and nearly on a level with the upper margin of the ball articular surface of the centrum. Again, the posterior zygopophyses appear to have a more solid base than those in the figure quoted. On the right side of the bone the transverse process is practically complete, and would seem to be constructed on somewhat more solid lines than in the type examples.

The articular ball of the centrum is very convex and projecting (Pl. 8, fig. 4). The neural canal is distinctly broad-oval at the posterior end, as usual in this reptile, and at the opposite or

1 Owen. Odontography, pt. ii., 1841, p. 265.

2 Carne: "Phosphate Deposits in Limestone Caverns in New South Wales." Ann. Rept. Dept. Mines N.S. Wales for 1914 (1915). p. 191, plan, etc.

3 Owen. Phil. Trans., 171, pt. iii., pl. 34.

anterior end is wide transversely. The following are the principal measurements:—

	inches.
Length of centrum	3
Breadth of the same behind the ball	$1\frac{3}{4}$
Vertical, or longitudinal, diameter of ball	$1\frac{1}{2}$
Transverse ditto	$1\frac{5}{8}$
Vertical, or longitudinal, diameter of centrum	$1\frac{3}{8}$
Fore and aft diameter of cup	$1\frac{1}{8}$
Transverse diameter of cup	$1\frac{7}{8}$
Transverse diameter of anterior outlet of neural canal	$\frac{5}{8}$
Transverse diameter of posterior ditto	$\frac{4}{8}$

The remains of *Megalania prisca*, inclusive of *Notiosaurus dentatus*, have now been found in fluviatile, mound spring and cave deposit, as follows:—

Fluviatile deposits	Condamine River and its branches (King Creek, &c.), Queensland; "Near Melbourne,"[1] Victoria; South Australia; Castlereagh River, N. S. Wales.
Mound Spring deposit	Cuddie Springs, East of Gulgongong, N. S. Wales.
Cave deposits	Wellington Caves Reserve, N. S. Wales.

3.—Lacertilian Dermal Armour. (Pl. 8, Figs. 6-9).

For two very interesting fragments from the Opal beds of Lightning Ridge, near Walgett, New South Wales, I am indebted to Mr. T. Wollaston, of Adelaide. Both are formed of roughly hexagonal bony pieces (Pl. 8, figs. 6-8), firmly united by their margins in alternate series. Each component plate is limpet-shell-shaped, more or less, obliquely and unequally conical fore and aft, with a backwardly projecting obtuse apex, with a tendency to overlap in a similar direction. One specimen (Pl. 8, figs. 6, 7) is composed of six larger plates, with three smaller along one of its margins forming, as it were, a border. The second specimen (Pl. 8, fig. 8) comprises five plates of a like nature, and again with three smaller marginal pieces.

These plates are thick, of a compact and bony tissue, the structure of the latter displayed on the inner surface; externally they are highly rugose, the rugosities papilla-like, and usually separate from one another, but here and there becoming semi-confluent, with the narrow interspaces between the papilla often pitted. When

1 It would be interesting to know the exact locality.

examined externally, they appear to be separate from one another, but on the inner surface (Pl. 8, fig. 7) all are anchylosed into a solidity. In one instance at least, some of the papillae have run together, forming three radiating lines from the apex to points on the circumference.

When these fragments first came under my notice, I was struck with a general resemblance to the scale armour of some lizards, and as one naturally turns first to the native fauna for comparisons and affinity, the "Shingle-back" or "Stump-tail" (*Trachysaurus rugosus*) claimed attention. This remarkable species is "clothed with an armour of rough, thick, brown scales (Pl. 8. fig. 9), which give it very much the appearance of a living pine cone." In the Shingleback the dermal armour is osseous, with a horny epidermal covering, as usual, but in the present instance the osseous plates only are presented to us.

The living *Trachysaurus* measures some fourteen inches in length, and if these consolidated scutes represent a reptile allied to the Shingle-back, and are to be accepted as a guide to its relative size, it may not have greatly exceeded the latter in dimensions, the largest scutes on the tail of the Shingle-back measure on an average 9×11 m.m., whilst the cross diameters of the fossil plates are 12×13 m.m.

There is agreement between the recent species and the petrified plates in the general outline of the latter, and the granular sculpture, or ornament. On the tail plates there is a tendency to a posterior pointed apex as in the Lightning Ridge fragments, but the markedly conical elevation of the latter is not seen in the scales of *T. rugosus*.

I have already spoken of the smaller plates at the sides of the fossil fragments, and if an examination be made of the creases between the hind limbs and tail of *T. rugosus*, similar small scales will be found bordering the larger lateral ones. From this, I venture to suggest that the Lightning Ridge fragments are from an approximately similar position in the extinct form.

I am unable to compare my specimens with the few Lacertilian dermal scutes known from the Cretaceous elsewhere, both from the absence of comparative material and literature. In the meantime I ask those who may have reptilian material from the Upper Cretaceous of either Lightning Ridge or White Cliffs, to carefully examine it, with the view of throwing further light on a very interesting subject.

4.—Opalised Reptilian Dentary from Lightning Ridge.
(Pl. 8. figs. 10 and 11).

To Colonel R. E. Roth, D.S.O., M.R.C.S.E., the Australian Museum is indebted for sundry reptilian and molluscan remains from the above locality. The most attractive of these is a small dentary (Pl. 8. figs. 9 and 10), posteriorly broken just at the symphasis, and incomplete forward. There are six teeth set in sockets in an alveolar groove, and supported by the outer alveolar wall, in other words, a pleurodont dentition; the entire specimen is one and three-quarter inches long, the bony tissue being wholly converted into ordinary blue-black opal.

The most complete tooth measures five millimetres from the bottom of the alveolar groove to the tooth apex, but at what I take to be the posterior end of the specimen, the socket visible there is quite ten millimetres deep, and as the slightly curved teeth extend to the bottom, it follows that some of them, at least, attained a length of fifteen millimetres; at the anterior end the alveolar groove is shallower, about six millimetres, the bone itself has a maximum width of fifteen millimetres. The teeth are faintly striate to about the middle of their exposed length, and opalisation has removed all trace of osseous structure throughout the specimen.

Our present knowledge of the Australian Cretaceous reptilian fauna is a very limited one. A few Ichthyopterygian and Sauropterygian remains, a Chelonian or two, a Saurischian (*Agrosaurus macgillivray*), Crocodilian scutes, and other dermal scutes of an unknown reptile,[1] possibly Stegosaurian, about complete the list.

In looking round for relatives of this very beautiful little fossil, I was at first led towards the Ichthyopterygians, but being unsuccessful in this direction, I took the precaution of consulting my former colleague, Dr. Smith Woodward, who suggested a provisional reference to the American Cretaceous and imperfectly known genus *Botosaurus*, L. Agassiz. There is certainly a resemblance to Leidy's figures, but there are also discrepancies in the form of the teeth which it will be well to point out.

In *Botosaurus harlani*, Leidy said that one of the teeth had a mammiliform crown and a gibbous fang; another, the penultimate or last tooth possessed a laterally compressed mammiliform crown,

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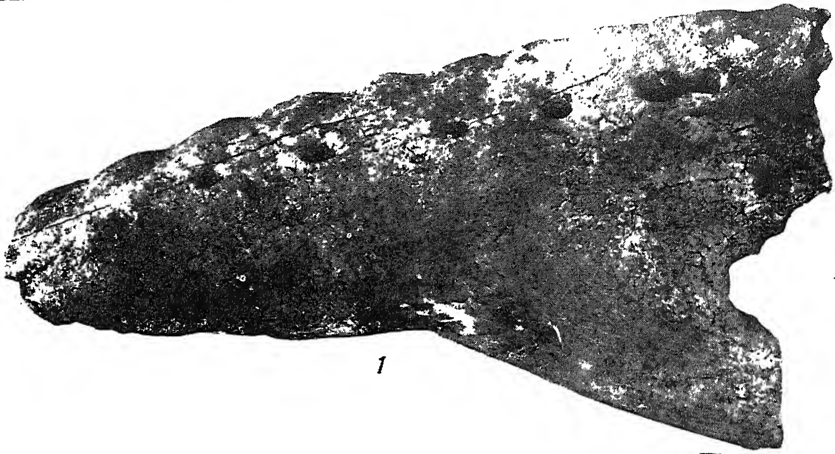
1 Etheridge. Rec. Austr. Mus., v., No. 2, 1904.

2 Leidy: "Cretaceous Reptiles of the United States." Smithsonian Contrib. Knowledge, 192, 1865, p. 12.



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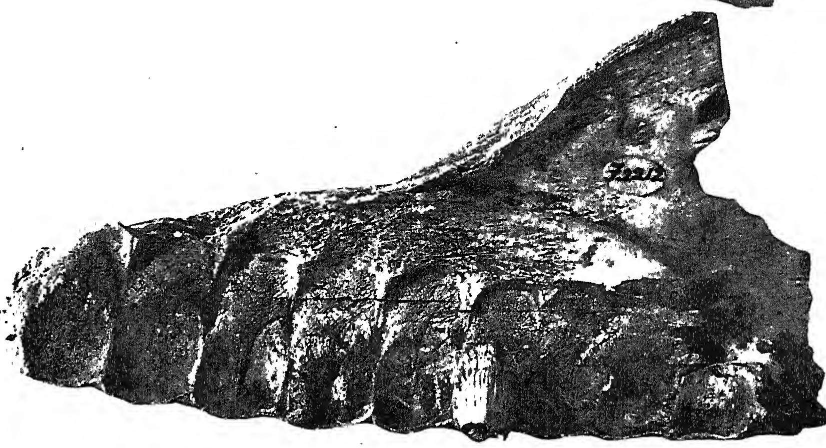

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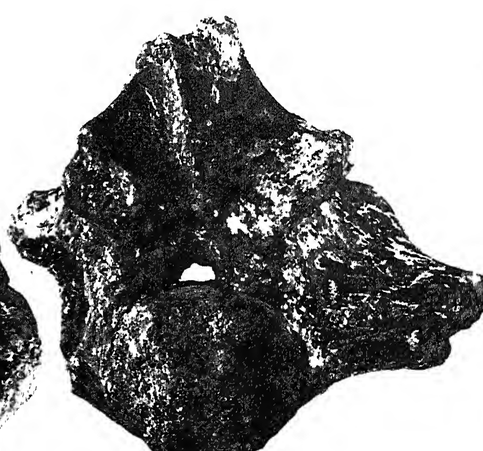

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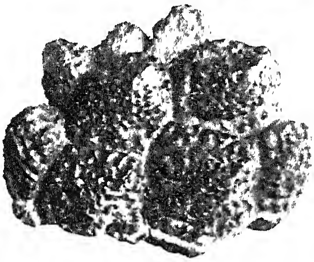

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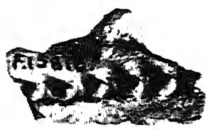

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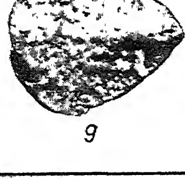

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with its outer and inner surfaces separated by a prominent ridge, and its enamel strongly corrugate.[1]

The teeth of the Lightning Ridge reptile, on the other hand, are, so far as at present known, alike, sharply conical above the alveolar border, with a slight inward curvature, and barely any difference in size amongst the six. By their regularity of disposition and similarity of form, these teeth partake far more of the Gavilian than the Crocodilian type, with the exception of those of *Crocodilus johnstoni*, Krefft, inhabiting the upland waters of North Australia. In this comparatively small species the forward teeth are of the same type as those of our fossil, within certain limits of the same size, and inwardly curved.

This remarkable fossil is certainly worthy of a name, and for it I propose that of *Crocodilus (? Botosaurus) selaslophensis*[2]

EXPLANATION OF PLATE VIII.

Fig. 1. Exterior view of right dentary, with six arterial foramina, the terminal posterior dumb-bell-shaped, of *Megalania prisca*, Owen.

Fig. 2. Interior view of the subject of Fig. 1 with impressions of seven teeth along the alveolar border, one nearly entire tooth and a partially decayed one, nine in all.

Fig. 3. Posterior view of the dorsal vertebra from the Wellington Cave Reserve, with the transverse process on the right hand side of the figure nearly complete.

Fig. 4. Side view of the subject of Fig. 3, exhibiting the rotundity and convexity of the articular ball of the centrum.

Fig. 5. Palate of the Water Monitor (*Varanus salvator*) for comparison of the right and left dentaries with Fig. 2.

Fig. 6. Six large and three small dermal scutes of a Lacertilian, exterior view.

Fig. 7. The same specimen, inner view.

Fig. 8. Another example with five large and three small dermal scutes.

Fig. 9. Osseous dermal scute of the Shingle-back (*Trachysaurus rugosus*) – × 11 diam.

Fig. 10. *Crocodilus (? Botosaurus) selaslophensis*, Eth-fil. Portion of ramus with six teeth seen from the side—nat.

Fig. 11. The same specimen seen from above—nat.

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1 Leidy. *Loc. cit.*, p. 13.

2 σελας = lightning; λοφος = ridge; and *ensis*.

[PROC. ROY. SOC. VICTORIA, 29 (N.S.), PART II., 1917].

ART. XII.—*New or Little-known Victorian Fossils in the National Museum.*

PART XX.—SOME TERTIARY FISH-TEETH.

BY FREDERICK CHAPMAN, A.L.S., &c.
(Palaeontologist to the National Museum, Melbourne).

(With Plate IX.).

(Read December 14th, 1916),

Introduction and Summary.

The series of fossil remains now described, although small, is especially noteworthy on account of the rarity of the specimens. The following genera are represented:—

CARCHAROIDES.—Instituted in 1901 by Ameghino for selachian teeth from the Patagonian Tertiary, having the dual characters of *Lamna* and *Carcharodon.* They have now been found at two Janjukian localities in Victoria, thus affording an additional link in the evidence of the contemporaneity of the South American and Victorian strata.

ODONTASPIS.—One of the largest Tertiary species of the type of the living Bull-shark is *O. elegans*, here noted in detail, and first recorded, but without locality, from Victoria by McCoy.

PRISTIOPHORUS.—The side-gilled saw-fish is almost unique amongst fossils. Its rostral teeth are here shown to occur in the Tertiaries of Victoria and New Zealand.

PRISTIS.—The teeth of this sawfish were unknown in the Southern Hemisphere, although several species have been recorded from Tertiary deposits in England and North America. The Victorian fossils appear to be most nearly allied to the Mediterranean species, Pristis antiquorum, and not to the Indian and Australian form.

MYLIOBATIS.—This is the first recorded occurrence of the genus in undoubted Victorian Miocene beds; the oldest example hitherto known occurring in the Mallee at

about the junction of the Miocene and Lower Pliocene (Janjukian and Kalimnan).

SARGUS.—A representative of this genus is common in the Miocene of New Zealand, but this is its first occurrence in Victoria, in beds of similar age.

Description of Specimens.

PISCES.

Fam. CARCHARIIDAE.

Genus **Carcharoides**, Ameghino.

Carcharoides totuserratus, Ameghino. (Plate IX., Figs. 1 and 2.)

Carcharoides totuserratus, Ameghino, 1901, Bol. Acad. Nac. Cienc. Cordoba, vol. XVI., p. 102. Idem, 1906. "Les Formations Sedimentaires du Crétacé Supérieur et du Tertiaire de Patagonie." Anales del Museo Nacional de Buenos Aires, ser. III., vol. VIII., p. 183 (footnote), and woodcut, fig. 50. Chapman, 1913, Vict. Naturalist, vol. XXX., pp. 142, 143.

Description.—The teeth of the Victorian specimens are, like those from Patagonia (of Patagonian age), of moderate size. The base is strong, but not so stout or heavy in proportion as in a tooth of the genus *Carcharodon*, but more akin to that of *Lamna*, and angularly inarched. The crown is strong and slightly and obliquely curved; apex sharp. External face depressed-convex, with a weak median sulcus extending for about 3 mm. from the junction of the base upwards. Internal face depressed-convex. Lateral cusps blunt in Ameghino's type, but acute in well-preserved specimens, as that from Torquay. Edges of crown and lateral denticles compressed, thin and bluntly serrate, the serrations varying from mere crenulae to stout serrations. Edge view of crown shows a slight flexure.

Dimensions.—Ameghino's type. Total length, 26 mm. (crown, 18 mm.; base, 8 mm.). Width of crown at base, not including cusps, 10 mm.; thickness, 4 mm.

Specimen from Torquay. Total length, 24 mm. Width at base, 15.25 mm. Length of crown, 17 mm. Width of crown, 9 mm. Thickness of crown, 3 mm. Height of lateral denticles, 4.25 mm.; width, 3.25 mm.

Specimen from Waurn Ponds. Total length, 22 mm. Length of crown, 19 mm. (base imperfect). Width of crown at base, 9.75 mm. Thickness, 3.5 mm.

Observations.—When complete, this type of tooth is seen to be distinct from *Lamna*, *Carcharias* (*Prionodon*) or *Carcharodon*. From the former it differs in its serrated edges, and from the two latter genera in the shape of the base and the presence of lateral denticles.

Occurrence.—Tertiary (Janjukian). Waurn Ponds, near Geelong; pres. by Mr. S. R. Mitchell (tooth consisting of crown and part of base), W. of Rocky Point, Torquay. (A nearly perfect specimen in excellent preservation, showing the crown and two lateral denticles, with a part of the base.) From the collection of the late Dr. T. S. Hall, M.A.

Carcharoides tenuidens, Chapman. (Plate IX., Fig. 3.)

cf. *Carcharias* (*Prionodon*) *acutus*. non Agassiz, Chapman and Pritchard, 1904, Proc. Roy. Soc. Vict., vol. XVII. (N.S.), pt. I., p. 274.

Carcharoides tenuidens, Chapman, 1913, Victorian Naturalist, vol. XXX., pp. 142, 143, and woodcut. Idem, 1914, Australasian Fossils, p. 270, fig. 131A.

Description.—Holotype. Tooth of slender habit. Root slightly arched and moderately stout. Crown acutely triangular, flattened on the outer face near the junction with the root, and otherwise depressed convex; inner face roundly convex; edge view showing a wide recurvation of the lateral line, as in *Odontaspis*. Edge crenulate, with blunt serrae. Lateral denticles well developed, sharp, and turned towards the crown.

Dimensions.—Total length from base to apex, 20.25 mm. Extreme width at base of root, 12 mm.; thickness, 4.5 mm.; width of crown at junction with root, 7.25 mm.; thickness, 3.75 mm. Length of lateral denticle, 3.75 mm.

Observations.—The serrated crown from Waurn Ponds described by Dr. Pritchard and myself in 1904, and doubtfully referred to *Carcharias* (*Prionodon*) *acutus*, Ag. appears to belong to the above species, with which it agrees in its narrow crown and acute apex, as distinguished from that of the preceding species, *C. totuserratus*, which has a broader crown.

Occurrence.—Tertiary (Janjukian). Waurn Ponds Quarry. Type specimen collected and presented by Mr. J. F. Mulder. An imperfect tooth (crown only), from J. F. Bailey coll.; same locality.

Fam. Limnidae.

Genus **Odontaspis**, Agassiz.

Odontaspis elegans, Agassiz sp. (Plate IX., Fig. 4.)

Lamna elegans, Agassiz, 1843, Poissons fossiles, vol. III., p. 289, pl. XXXV., figs. 1-5 (non figs. 6, 7); pl. XXXVIIa., fig. 59 (non 58). R. W. Gibbes, 1849, Journ. Acad. Nat. Sci. Philad., ser. 2, vol. I., p. 196, pl. XXV., figs. 98-102 (? figs. 96, 97). Dixon, 1850, Foss. Sussex, p. 203, pl. X., figs. 28-31. McCoy, 1867, Ann. Mag. Nat. Hist., ser. 3, vol. XX., p. 192. Id., 1874, in Brough Smyth's Prog. Rep. No. I., p. 35. Johnston, 1877, Proc. R. Soc., Tas., for 1876, p. 86.

Lamna huttoni, Davis, 1888, Trans. Roy. Dubl. Soc., ser. 2, vol. IV., p. 15, pl. III., fig. 1.

Odontaspis elegans, Ag. sp., Smith Woodward, 1889, Cat. Foss Fishes, Brit. Mus. (Nat. Hist.), pt. I., p. 361.

This species of *Odontaspis* is perhaps the rarest of the genus in Victoria. It did not occur in the series of Australian Tertiary fish-teeth examined by Dr. G. B. Pritchard and myself in 1904, but was recorded by McCoy in 1867 under the name of *Lamna elegans* from Victorian Miocene beds, and was also noted by R. M. Johnston from Tasmania in his "Notes on the Tertiary Beds of Table Cape."

It is readily distinguished from the other Australian species of *Odontaspis* by its stouter build and strong divergent roots. There is little doubt that this world-wide species is also represented in New Zealand by Davis' *Lamna huttoni*, the type of which has a rather long crown, gently but sinuously reflexed. The Victorian specimens are destitute of lateral denticles, owing to attrition or partial decay of the base.

Occurrence.—Tertiary (Janjukian). Waurn Ponds, near Geelong. Fyansford Hill, near Geelong. Presented by Miss Lenna Bryan.

Fam. Pristiophoridae.

Genus **Pristiophorus**, Müller and Henle.

Pristiophorus lanceolatus, Davis sp. (Plate IX., Fig. 5.)

Lamna lanceolata, Davis, 1888, Trans. R. Dubl. Soc., ser. 2, vol. IV., p. 20, pl. III., figs. 12*a-d*.

Observations.—The fossil fish-tooth figured by J. W. Davis as cited above has long been a puzzle as to its real relationship. That

author himself was dubious about referring it to *Lamna*. Dr. A. S. Woodward, in his "Catalogue of Fossil Fishes,"[1] remarks upon it as follows:—

"The so-called *Lamna lanceolata*, J. W. Davis (Trans. Roy. Dublin Soc., 2 vol. IV., 1888, p. 20, pl. III., fig. 12), from New Zealand, is founded upon a tooth evidently not Selachian."

Whilst studying the structure of the rostral teeth in the living *Pristis* and allied genera, I was struck with the resemblance of Davis's fossil with the teeth of the Hobson's Bay Saw-shark, *Pristiophorus*. Their generic identity was confirmed from the following features common to both. The flattened crown of the tooth is equally, slightly convex on both surfaces. The base of the tooth is not furnished with a definite semi-calcified root as in *Lamna*, but appears to be torn from its base, suggesting a cartilaginous attachment. The tooth curves gently backwards, and at its junction with the basal cartilage the osteodentine is clearly marked off from the base. This line of attachment bends down to the anterior margin in both living and fossil species. The hollow root of the fossil teeth further indicates a hollow or membranous base seen on the rostral margin of the living *Pristiophorus*.[2]

The teeth of *Pristiophorus lanceolatus* are closely comparable to those of *P. nudipinnis*, Günther,[3] (Pl. IX., fig. 6), a saw-fish found in Hobson's Bay, Port Phillip, with these differences:—

The fossil specimens are larger, stouter and more strongly curved. The size of the Victorian specimen indicates a fish of about four and a-half feet long, whilst that from New Zealand would have been about six feet or more.

The genus *Pristiophorus* is rare in the fossil condition, being only represented by some detached vertebrae from the Molasse of Baltringen, Würtemberg,[4] and by an undescribed form from the Upper Cretaceous of Mount Lebanon (Smith Woodward).

J. W. Davis's specimen came from the Oamaru series at Castle Hill Station, Canterbury, N.Z.

Occurrence.—Tertiary (Kalimnan). Beaumaris. Pres. by Mr. F. A. Cudmore.

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1 Part i., 1889, p. 410.

2 In working out the relationships of this and other fossil specimens I have been kindly assisted by Mr. J. A. Kershaw, F.E.S., Curator of the Museum, who has given facilities for examining recent specimens.

3 Günther. Cat. Foss. Fishes, Brit. Mus., vol. viii., 1864, p. 432. McCoy, Prod. Zool. Vict., vol. i., 1885, pl. lvi., fig. 2.

4 Hasse, C. "Das natürl. Syst. Elasm., Besond. Theil," p. 103, pl. xiii., figs. 6, 7.

Fam. PRISTIDAE.

Genus **Pristis**, Latham.

Pristis cudmorei, sp. nov. (Plate IX., Fig. 7).

Description.—Dermal teeth of rostrum. flattened-conical and curved; bluntly pointed. Inner, concave edge rounded; the convex margin cultrate. Base nearly straight across, but slightly hollowed below, the surface in contact with the cartilaginous socket of the rostrum being roughened for attachment. Surface of tooth even but for a few longitudinal grooves around the base. The surface of the tooth when magnified shows numerous longitudinal striae, very fine and distinct.

Dimensions of Holotype.—Length of tooth, 17.5 mm.; width at base, 7.5 mm.; greatest thickness, 4 mm. The smaller specimen has a length of 15 mm.

Observations.—None of the fossil forms about which I have been able to gather details show any decided resemblance in shape to the above specimens, excepting *Pristis ensidens*, Leidy,[1] from the Miocene phosphate beds of South Carolina, but this form has a straight-sided tooth which is broader at the base. Undoubtedly the nearest representative is the living *Pristis antiquorum*, Latham, found in the Mediterranean and the warmer parts of the Atlantic. The teeth of the rostrum in this species are almost identical in shape, especially the anterior teeth, the only difference being the coarser striae on the teeth of the living species. Strangely enough, the Indian and Australian species (*P. zysron*, Bleek) has dermal teeth of a very different type, they being thick, long and straight, and with a coarse, fibrous structure near the base.

Occurrence.—Tertiary (Kalimnan). Beaumaris, Port Phillip. Two teeth referred to the above species were found by Mr. F. A. Cudmore, after whom the species is named, in recognition of his many interesting palaeontological discoveries.

Fam. MYLIOBATIDAE.

Genus **Myliobatis**, Cuvier.

Myliobatis moorabbinensis, Chapman and Pritchard. (Plate IX., Fig. 8.)

Myliobatis moorabbinensis, Chapman and Pritchard, 1907, Proc. R. Soc., Vict., vol. XX. (N.S.), pt. I., p. 60, pl. V., figs. 1-3.

1 Journ. Acad. Nat. Sci. Philad., ser. 2, vol. viii., 1877, p. 252, pl. xxxiv., figs. 31, 32.

Chapman, 1914, ibid., vol XXVII. (N.S.), pt. I., p. 57, pl. X., fig. 57.

Observations.—The median palatal teeth referred to under the above name all differ in being more depressed, and having more closely set denticles than those of the living *Myliobatis australis*, Macleay.

M. moorabbinensis has been previously found in the Kalimnan of Beaumaris; and in the borings in the Mallee ranging from Janjukian to Kalimnan.

The tooth from Torquay is even more slender and depressed than the Beaumaris specimens, but evidently belongs to the same species. This is the earliest appearance of the genus in our Tertiary beds.

Occurrence.—One example from the Tertiary (Janjukian). Bird Rock Cliffs, Torquay, near Geelong. Pres. by Mr. W. J. Parr.

Fam. SPARIDAE.

Genus **Sargus**, Cuvier.

Sargus laticonus, Davis. (Plate IX., Fig. 9.)

Sargus laticonus, Davis, 1888, Trans. R. Dubl. Soc., Ser. 2, vol. IV., p. 43, pl. VII., figs. 3-8.

Observations.—This genus and species has not been recorded previously from the Australian Tertiary strata, although it is a well-known fossil in the New Zealand Oamaru system. It is there found with some frequency in the limestone beds of Coleridge Gully. Broken River, Castle Hill, Trelissic and Canterbury. It is especially interesting to find this fossil in our Batesford fauna, since the writer has more than once referred this series to a similar period as the Oamaruian.

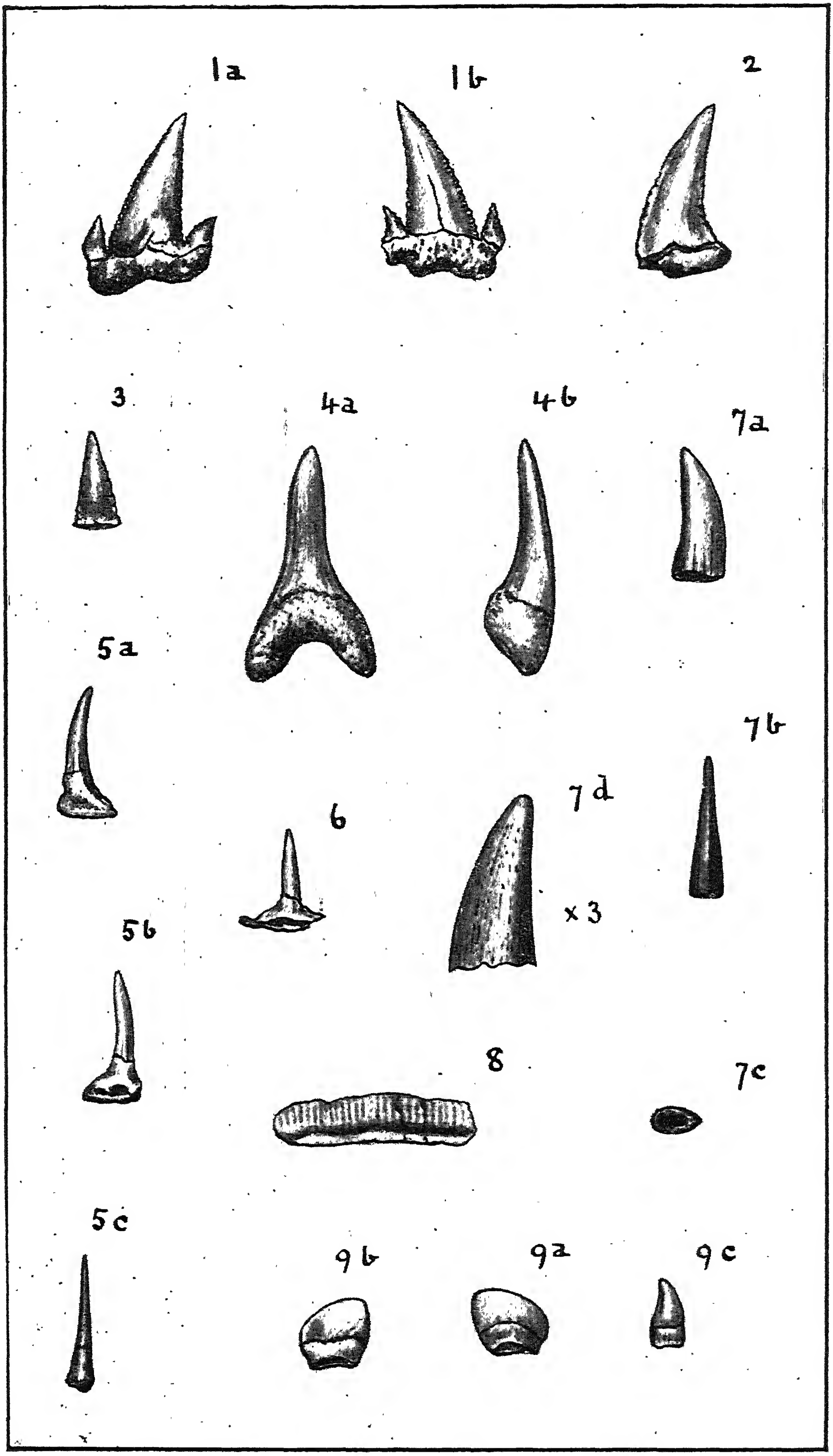
The specimen here figured is one of the anterior cutting teeth, and is exceptionally broad, but not unlike Davis's figure 7 on pl. VII. of his paper.

Occurrence.—Tertiary (Janjukian). Limestone quarries, Batesford, near Geelong. Pres. by Mr. D. Culliney.

EXPLANATION OF PLATE IX.

Fig. 1.—*Carcharoides totuserratus*, Ameghino. 1*a*, external face; 1*b*, internal face. Tertiary (Janjukian). Torquay. T. S. Hall coll.

,, 2.—*Carcharoides totuserratus*, Amegh. Internal surface of tooth. Tertiary (Janjukian). Waurn Ponds, near Geelong. Pres. S. R. Mitchell.



F.C. ad nat. del.

Tertiary Fish-Remains from Victoria.

" 3.—*Carcharoides tenuidens*, Chapman. External face. Tertiary (Janjukian). Waurn Ponds, near Geelong. Pres. by J. F. Mulder.

" 4.—*Odontaspis elegans*, Agassiz sp. 4*a*, internal face; 4*b*, edge view. Tertiary (Janjukian). Fyansford, near Geelong. Pres. by Miss L. Bryan.

" 5.—*Pristiophorus lanceolatus*, Davis sp. 5*a*, upper surface of tooth; 5*b*, lower surface; 5*c*, edge view.

" 6.—*Pristiophorus nudipinnis*, Günther. A rostral tooth, from the lower side. Living, Hobson's Bay, Port Phillip.

" 7.—*Pristis cudmorei*, sp. nov. 7*a*, lateral face of dermal tooth; 7*b*, edge view, anterior; 7*c*, basal aspect; 7*d*, apex of tooth magnified 3 diameters. Tertiary (Kalimnan). Beaumaris, Port Phillip. Pres. by F. A. Cudmore.

" 8.—*Myliobatis moorabbinensis*, Chapman and Pritchard. Lower or articulated surface of median tooth. Tertiary (Janjukian). Bird Rock Cliffs, Torquay, Vict. Pres. by W. J. Parr.

" 9.—*Sargus laticonus*, Davis. 9*a*, anterior face of tooth; 9*b*, posterior face; 9*c*, lateral view. Tertiary (Janjukian). Batesford, near Geelong. Pres. by D. Culliney.

N.B.—All figures of natural size, excepting fig. 7*d*, which is magnified 3 diameters.

CORRIGENDA.

In Part XIX. of this series, vol. XXIX., pt. I., 1916, p. 90, line 2 from top, for "Holotype" read "Paratype"; line 4 from top, for "Paratype" read "Holotype."

[Proc. Roy. Soc. Victoria, 29 (N.S.), Part II., 1917].

Art. XIII.—*Contributions to the Flora of Australia, No. 25.*[1]

BY

ALFRED J. EWART, D.Sc., Ph.D., &c.

(Government Botanist of Victoria and Professor of Botany and Plant Physiology in the Melbourne University).

(Read December 14th, 1916).

Ailanthus glandulosa, Desf. "Chinese Tree of Heaven." (Simarubaceae).

Bacchus Marsh, J. W. Audas, October, 1916.

This tree, a native of China, is frequently grown in gardens or planted in reserves, etc.

In the Bacchus Marsh district it appears to spread on each side of a 300 yards length of road to a depth of 10 to 15 yards, possibly partly by sucker growth from planted trees. The plant also occurs along the Lerderderg River. When fully grown it forms a large tree, but the timber does not appear to have a great economic value. The plant may ultimately become naturalised, but the evidence for this is as yet insufficient.

Allium sphaerocephalum, L. "Round Headed Allium." (Liliaceae).

Warrnambool, L. Crawley, August, 1914.

A native of Europe, apparently not yet sufficiently established to be considered naturalised.

Amsinckia lycopsoides, Lehm. "Loose Amsinckia." (Boraginaceae).

Buninyong, Victoria, H. B. Williamson, November, 1915.

A native of California, U.S., America. This is a new locality in Victoria for this introduced plant, as it has previously been recorded from the north-Eastern district only. It may now be considered to be a definitely naturalised alien. It is apt to become a troublesome pest in arable land, and should be suppressed.

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1 No. 24 in the Proc. Roy. Soc. Victoria, vol. xxviii. (n.s.), p. 230, 1916.

BELLIS PERENNIS, L. "Perennial Daisy." (Compositae).

Fish Creek and Foster, C. French, jnr., September, 1916.

This naturalised alien is now spreading in pastures in South Gippsland.

BRACHYPODIUM DISTACHYUM, Beauv. (Gramineae.)

Dooen, Victoria, A. Dreverman, November, 1915.

It is a native of the Mediterranean regions and the Orient, and has not been previously recorded as growing wild in Victoria. It may be regarded as an exotic not yet sufficiently established to be considered naturalised.

Mr. Dreverman states that "the grass is very abundant in the immediate district, but for how long I do not know, since this is the first season I have noticed it. It is rather a coarse grower, possessing little value as a stock food."

BRASSICA NIGRA, Koch. "Black Mustard." (Cruciferae).

Shire of Dimboola, Mr. St. Eloy D'Alton, October and November, 1915.

This plant, a native of Southern Europe and temperate Asia, has apparently been introduced with impure seed, and is apt to become as troublesome as the Charlock in cornfields, if allowed to spread. It may be considered as an exotic not yet sufficiently established to be considered naturalised.

CALYCOTOME SPINOSA, Link. "Spiny Broom." (Leguminosae).

Koo-wee-rup Swamp, J. W. Audas, 27/10/15.

A new locality for this introduced plant. It is a native of North America.

CASSIA TOMENTOSA, Lam. "Woolly Senna" (Leguminosae).

Portland, J. W. Audas, September, 1916.

It is a native of tropical America, and has not been previously recorded as growing wild in Victoria. It may be regarded as an exotic not yet sufficiently established to be considered naturalised.

CERATOGYNE OBIONOIDES, Turcz. "Wing Fruit." (Compositae).

Underbool (H. B. Williamson, No. 1560), J. Malone, August, 1915.

In this curious little composite the young head externally closely resembles a single flower, and the few outer florets develop curious

winged fruits. It is recorded from isolated localities in West Australia, South Australia, New South Wales, and Queensland, and is a new addition to the Flora of Victoria. It has no economic value.

COLLOMIA LINEARIS, Nutt. (Polemoniaceae).

Beaconsfield, Victoria, J. R. Tovey, March, 1916.

Previously recorded as a garden escape from Romsey, and possibly in the process of naturalisation. It is a garden plant, native of North-West America, and appears to have no injurious properties, nor to be of any economic value.

COLOBANTHUS BILLARDIERI, Fenzl. "Coast Colobanth." (Caryophyllaceae).

Mt. Hotham, A. H. Taylor, December, 1915.

This mountain locality is a new record, since the plant is only recorded previously from the south-west coast of Victoria, and from Wilson's Promontory. It grows on Mt. Hotham in very wet places, in association with Oreomyrrhis pulvinifica.

DIGITALIS PURPUREA, L. "Common Foxglove." (Scrophulariaceae.)

McCrae Creek, J. W. Audas, 30/10/1915.

Spreading in the Gembrook district. Apparently in process of naturalisation. It is a native of Europe.

EREMOPHILA CRASSIFOLIA, F. v. M. (Myoporaceae).

Ngallo, near South Australian border, N.W. Victoria, C. F. Hawkins, October, 1916. (Williamson, No. 1589.)

Only previously recorded from South Australia; a new addition to the Flora of Victoria.

A specimen from Eucla, J. D. Batt, 1886, appears to belong to the same species, but has the leaves narrower and spathulate. It may be distinguished as a Western Australian form or variety (var. spathulata).

EREMOPHILA STURTII, R. Br. (Myoporaceae).

Mirbein, Victoria, D. B. Halked, 27/10/1915.

This species is given in Mueller's Census of Australian Plants as occurring in South Australia, New South Wales and Queensland, but not from Victoria. This was evidently an oversight, as there is a Victorian specimen from the Murray River, collected by Dallachy

half-a-century ago, in the National Herbarium. A second specimen from the same locality was seen by Bentham, but is not mentioned in the Flora Australiensis.

ERICA ARBOREA, L. "Tree Heath." (Ericaceae).

Wheeler's Hill, J. W. Audas, 11/8/16; Beaconsfield, Victoria, Mrs. L. R. Dancocks, December, 1916.

This shrub is now probably in the process of establishing itself as a naturalised alien in Victoria. The specimens collected at Wheeler's Hill were growing among thick scrub, and fully two miles from the nearest homestead. It is a native of South Europe.

GALEGA OFFICINALIS, L. (Leguminosae).

Ruffy, near Gobur, Victoria, William Noye, January and February, 1915.

A native of Southern Europe and South-Western Asia. It is a perennial herb, which stands drought well, and will grow on poor soil provided such is porous. It is an exotic not sufficiently established to be considered naturalised.

GNAPHALIUM CANDIDISSIMUM, Lam. "White Cudweed." (Compositae).

Tynong, J. W. Audas, 22/11/1915.

This introduced plant is already widely spread, and now appears to be extending deeply into Gippsland. It is a native of South Africa.

HIBISCUS DRUMMONDII, Turcz. (Malvaceae).

Minnipa, Eyre's Peninsula, South Australia, 11/11/1915.

A West Australian plant not previously recorded from South Australia.

HYPERICUM PERFORATUM, L. "St. John's Wort" (Guttiferae). (Hypericineae).

Majorca, near Maryborough, Victoria, F. Outtrim, January 1916. Muckleford, D. James, December, 1916.

This introduced pest, which is proclaimed under the Thistle Act for the whole State, has now made its appearance in these districts. This weed is (November, 1916) spreading from Rutherglen township, and has already reached the banks of the Murray River. It will be

likely to appear at various points of the lower reaches of the river after floods.

LAMARCKIA AUREA, Moench. "Golden Lamarckia." (Gramineae).

Moodemere, North Rutherglen, Murray River. It is growing in unusual abundance owing to the moist season, G. H. Adcock, November, 1916.

The grass is a native of Europe, Asia and Africa, and was first recorded in 1878. It has only a very slight pasture value.

LATHYRUS ANGULATUS, L. "Angular Pea." (Leguminosae).

Harcourt, C. French, jnr., November, 1916.

This plant, a native of Europe, is abundant at Harcourt, and has probably existed as a naturalised alien in Victoria for some time, but has been overlooked on account of its inconspicuous character and resemblance to a Vetch. It is now growing in all cultivated land in the district; stock do not seem to eat it readily. It is not recorded as a poisonous plant, but is worthy of investigation.

LAVATERA ARBOREA, L. "Common Tree Mallow." (Malvaceae).

Iona and railway enclosure, Garfield, J. W. Audas, 22/11/1915.

A new locality for this introduced plant. It is a native of Europe.

LEPIDIUM RUDERALE, L., var SPINESCENS. (Cruciferae).

Camperdown, Victoria, per G. H. Sinclair, March, 1916.

This spiny form of L. ruderale has the smaller branches developed into thorns, more irregular branching, the leaves reduced in size and the pods with hardly any notch on top. It was queried by Bentham as a variety spinescens of L. ruderale, and was recorded from South Australia. It is questionable, however, to what extent the two forms are related, as the spiny habit of the variety is very different from that of typical forms of L. ruderale.

LEPIDIUM VIRGINICUM, L. "Virginian or Wild Peppercress." (Cruciferae).

Ashburton, Victoria, W. B. Wilson, June, 1915.

A native of North America. This species is very close to L. ruderale, and cannot be distinguished from it unless both the flower and fruit are available. The petals are present, and the seeds are minutely margined in L. virginicum.

LINARIA VERSICOLOR, Moench. (Scrophulariaceae).

Red Jacket Creek, Victorian Alps, Mr. Gargeuvich, 1873; Newstead, F. M. Reader, 1910; St. Arnaud, T. O. Murphy, October, 1916.

This plant, a native of Europe, is now evidently establishing itself as a naturalised alien in Victoria. Some species of Linaria are poisonous, but the present species has not been tested. The plant, having rather handsome flowers, might be of some use for decorative purposes, but otherwise it has no known economic value.

ORTHOCARPUS PURPURASCENS, Benth. "Purple Orthocarpus." (Scrophulariaceae).

Maryborough, Miss Lydiard, 4/11/1915; Balmattum, Victoria, B. S. Budds, 26/11/15; Casterton, per J. Harris (Aust.), 30/11/15; Port Fairy, per W. S. MacPherson, 30/11/15; Casterton, November, 1915; Mokoan, J. B. Higgins, November, 1916.

This plant, a native of California, is injurious in pastures on account of its roots being parasitic on the roots of grasses. It is a freely seeding annual, introduced with fodder imported from North America.

The plant was previously recorded in Victoria from Euroa as an exotic not sufficiently established to be considered naturalised. In view of the wide distribution of the plant and its freely seeding habit is has now evidently definitely established itself as a naturalised alien.

PINUS PINASTER, Ait. "Star or Cluster Pine." (Coniferae).

Beaconsfield, 9/10/13, and Nar-Nar-Goon North, 25/10/1915, J. W. Audas.

This tree is now probably in the process of establishing itself as a naturalised alien in Victoria. The specimens collected were found growing among thick scrub, and were fully a mile away from the nearest planted trees.

PLANTAGO BELLARDI, All. "Hairy Plantain." (Plantaginaceae).

Ararat, E. J. Summers, November, 1914; H. B. Williamson, November, 1915.

The plant is a native of the Mediterranean regions and of Asia Minor, and has possibly been introduced into Victoria through the medium of bird seed. It differs widely from the ordinary plantains in appearance owing to its hairiness, and to the relatively large and prominent bracts between the flowers in the spike. The present

specimens are somewhat dwarfed, being only 2-4 inches in height, but agree in general characters with the above species. The plant has no economic value, and shows no signs of being a more troublesome weed than the ordinary plantains.

PLANTAGO PSYLLIUM, L. "Fleawort Plantain." (Plantaginaceae).

Nantawarra, 15 miles N.N.E. Pt. Wakefield, at the head St. Vincent's Gulf, S.A., Prof. T. G. B. Osborn, November, 1916.

This plant is a native of the Mediterranean regions, South-West India, and the Orient, and has not previously been recorded as a naturalised alien for Australia. Professor Osborn reports it to be spreading rapidly, and that it may become another Stinkwort, as it has an unpleasant smell. The seeds appear in the Pharmacopoeia as Semen Psyllii. These, from their resemblance to fleas, give the plant the name of "Fleawort." Their mucilaginous outer coat gives them the same properties as flax seed, viz., demulcent and emollient, and they can be used internally or externally.

STYLIDIUM. (Stylidiaceae).

Maiden, in his Census of New South Wales plants (1916) follows F. v. Mueller in reversing the nomenclature adopted by Bentham and by R. Brown, and using the name Candollea (Candolleaceae) for this genus and order. Schönland, in Englers Pflanzenfamilien, also followed the advice of F. v. Mueller on this matter without giving any other reasons. Mr. Maiden, however, gives definite reasons as follows:—"The genus Candollea (Candolleaceae or Stylidiaceae) was founded by Labillardiere in 1805. One year later the same author applied the name Candollea, apparently by an oversight, to another genus (Dilleniaceae). As both genera could not stand, Swartz changed Candollea (Candolleaceae) in 1807 into Stylidium, and consequently the order into Stylideae, but in doing so he made the twofold mistake of changing the name of the plant that had undoubtedly the claim to priority, and of selecting a name, Stylidium, already applied by Loureiro in 1790 to a genus of Cornaceae. There can be no doubt that F. v. Mueller was right in restoring the name Candollea to the genus first named so by Labillardiere (Candolleaceae). Labillardiere's second genus, Candollea (Dilleniaceae), of course, had to go, and is now united with Hibbertia."

In regard to Swartz's supposed errors, the genus of Cornaceae referred to is the Marlea of Roxburgh, which is now Alangium, Lam. The "Stylidium chinense" of Loureiro, Fl. Cochinch, ed.

Willdenow, 1793, p. 273, is usually referred to as a synonym to Marlea begoniifolia, Roxb., but since Loureiro describes it as having the corolla inferior and the drupe superior, it cannot belong to this genus at all, and has become a lost name without an owner. It is not advisable to use lost names of this kind in founding new genera, but it is quite another matter to suppress a generic name attached to well-defined species because 12 years earlier the name was applied to a species of plant which cannot now be identified.

The true history of the names of Stylidium and Candollea appears to be the reverse of that given. Swartz published the name of Stylidium in 1805 (Willdenow spec., Pl. IV. (1805), 146), and at a later date, 1807, repeats it (Magaz. Ges. Naturf. Fr. Berlin. I., 1807, p. 48).

In the same year (1805) Labillardiere published the names Candollea (Candolleaceae) for the same genus and order. Finding that Swartz's name had priority, Labillardiere then used the name Candollea in the following year for a genus of Dilleniaceae, now submerged in Hibbertia.

Apart from the fact that nearly all the species of the genus have been described under the name of Stylidium, namely, 90, as compared with 9, there are no valid reasons for changing the name adopted by Bentham and by R. Brown. I have gone fully into this matter because of the confusion likely to occur, if the plants known as Stylidium in Victoria are to be named Candollea in New South Wales.

TRICHOLAENA TENERIFFAE, Parl. "Red Natal Grass." (Gramineae).

This South African grass was introduced into Queensland many years ago, and has there become fully naturalised. It has since been carried to Victoria, and grows well at Mortlake and in the Western District, where it is now naturalised. It is of some value as a pasture grass, particularly in dry soils, being somewhat drought resistant, but is by no means in the first rank as a pasture grass, and is apt to become a troublesome weed in gardens and cultivated ground. It is not suitable for a pasture grass in a rotation series, where pasture follows cultivation.

ZYGOPHYLLUM OVATUM, Ewart and White. (Zygophyllaceae).

Alawoona (Trans-Murray Scrub), October, 1915, and Poochera, Eyre's Peninsula, South Australia, J. M. Black, November, 1915.

This species was first described from West Australian specimens, then afterwards found in Victoria, and now in South Australia, thus bridging the geographical gap in distribution.

[Proc. Roy. Soc. Victoria, 29 (N S.), Part II., 1917].

Art. XIV.—*A Disease or Teratological Malformation of Lucerne.*

By ELLINOR ARCHER, B.Sc.

(With Plate X.).

(Read December 14th, 1916).

Description of Abnormality.

The curious malformation about to be described was found on two specimens of lucerne received from different parts of Victoria, one being from the Werribee Irrigation Settlement, and the other from Echuca. They had both been collected in February, 1916, which was an exceptionally dry month.

The only parts to be affected by the deformity are the flower heads. The main stalks and the leaves are all normal, except a few small leaves at the termination of the main stalk, which show the terminal leaflet very much elongated in proportion to the lateral leaflets. The lower leaves and stem show symptoms of rust, caused by Uromyces striatus, but this is hardly likely to have any connection with the malformation.

The place of true flowers has been taken by clusters of small, indefinite heads, which show no special structure until they are examination microscopically.

These heads, as far as could be judged from the dried specimen, were dull grey in colour, with a faint suggestion of the purple characteristic of normal flowers.

If each head is taken to represent a flower, the inflorescence will be found to have increased in complexity from a simple raceme to a raceme of racemes which may be several times compound.

The main axies are normal, but the secondary are somewhat elongated, and bear still smaller axies instead of forming the peduncles of the flowers. The bracts to the main and secondary axies are normal.

Microscopic examination of the heads shows these axies to be terminated by masses of rounded growing points, which are enveloped by what may be described as small, narrow, simple bracteate leaves. Apparently all the growing points ultimately develop into these abnormal leaves, there being no true flowers or rudiments of parts of flowers to be found on either specimen.

The actual growing points show no special feature, being simply rounded masses of meristematic cells, with large granular nuclei. Careful examination of the bracteate leaves shows them to be small structures not more than two or three layers of cells thick, and varying very much in length, those placed lowest on the axis being the longest.

A rudimentary vascular strand can be found in all, and in the largest a few spiral and annular vessels are developed. Transverse section shows no distinction into palisade parenchyma and spongy mesophyll, but the internal cells are differentiated from the epidermal by being smaller and having thinner walls. A few of them terminate in a curious unicellular, hair-like projection. The larger bracts show a few stomata, but the most noticeable feature is the extensive deposit of calcium oxalate crystals along the vascular strand. These crystals occur in the same form along the mid-rib of normal foliage leaves, but as the bracts are so much smaller the crystals appear to be more prominent.

It would be impossible to say whether these bracts represent abortive foliage or floral organs. From their position and suggestion of colour they seem to represent the floral whorls. They are indefinite in size, number and position, but they appear to wrap round and protect the young growing points.

Normal hairs occur at the base of a cluster of heads and bracts. These hairs have not suffered in the general abortion, and consequently appear rather large in comparison with the rest of the

Sections.

Microtome sections of the material were made, and carefully stained and examined. Some of the stains used were methyl, blue, fuschin, safranin and gentian violet.

A careful examination made for any sign of parasitic fungi gave a negative result. If there had been any hypha present these should have been clearly stained by the methyl blue or safranin. No hypha could be seen, and the cells showed no sign of disintegration. Staining with concentrated alcoholic solution of Fuschin revealed numerous granules, varying very much in size. These were embedded in the cell walls or lining layers of protoplasm. They were most numerous in sections passing through the phloem of vascular bundle of the stems; very few could be distinguished in the very young growing points or the younger bracts.

High-power examination with an oil immersion lens did not reveal any structure in these granules. The sections were tested with iodine for starch, but the granules gave a negative reaction. They were probably proteid in character, as similar granules which have been proved to be proteid have been found in other plants. Further investigation is needed to make sure of this.

Sections of normal lucerne, which were subjected to the same embedding and staining processes, showed no trace of the granules, but here again more work must be done before the evidence is entirely satisfactory.

Staining with gentian-violet showed the cortical cells, abnormal stem and bracteate leaves to be densely packed with small, rod-like structures. These did not stain themselves, but showed clearly in the coloured protoplasm. They could be seen to be actually embedded in the protoplasm of the cell, and were not in the cell sap.

These gave a good positive reaction with chlorozine iodine, and a faint blue with strong solution of iodine in potassium iodide, which proves them to be an unusual form of young starch grains, or ones in which the cellulosic basis is more prominent than the granulose. They were especially numerous in sections of leaves from the abnormal plant.

Gram's special staining method to indicate the presence of bacteria in cells gave a negative result.

Culture Solutions.

The only growth which could be definitely traced as originating from the lucerne was the fungus Macrosporium, and this was found to develop from both specimens.

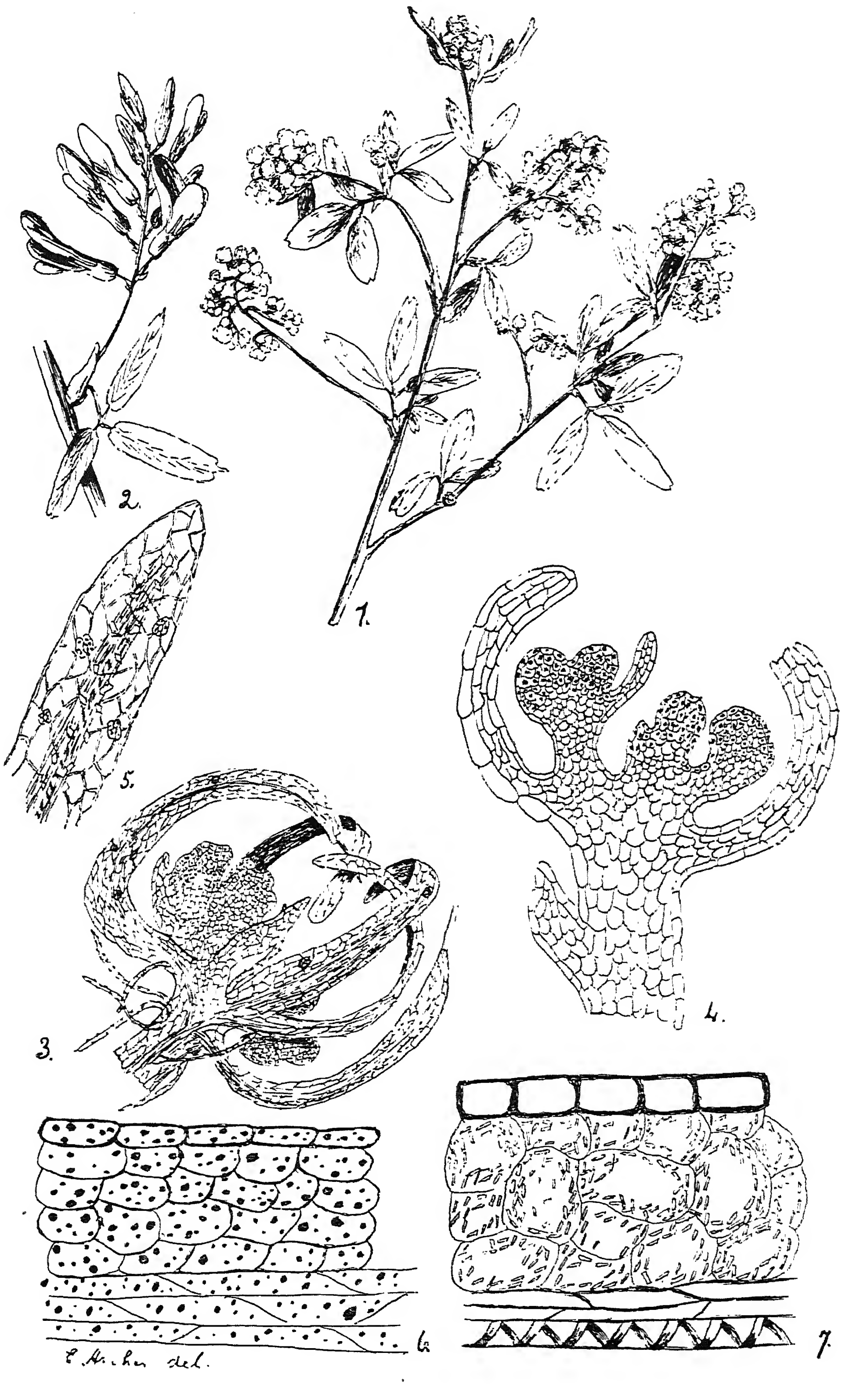
Very careful examination of the dried material showed the presence of macrosporium hyphae on the bracts themselves.

As macrosporium is usually a superficial fungus, and as it has been proved that there is no endophytic fungus present, it is very unlikely that it is the primary cause of the malformation.

Cause of Malformation.

As far as the investigation has gone at present it would be impossible to state definitely the cause of the abnormality, but it is possible to exclude some factors which might have affected the plant.

1. The malformation does not appear due to parasitic fungi.
2. There is no indication of the presence of destructive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insects, the bites of which might very easily have caused the proliferation of growing points.

3. The tissues do not seem to be infected with bacteria, and the cells do not show abnormality of size or shape, which is usually the case in the presence of bacteria.

The abnormal starch grains and proteid granules point to abnormal nutrition, and the fact that both specimens came from dry country, and were produced during a drought period, may possibly have something to do with the cause.

DESCRIPTION OF PLATE X.

Fig. 1.—Stem leaf and infloresence of abnormal plant.
,, 2.—Inflorescence of normal lucerne (Medicago sativa).
,, 3.—Head of abnormal material, showing growing points and bracteate leaves (magnified low power).
,, 4.—Section of growing points and bracteate leaves (magnified low power).
,, 5.—Single bracteate leaves (magnified high power).
,, 6.—Section showing proteid granules (magnified high power).
,, 7.—Section showing starch grains (magnified high power).

[Proc. Roy. Soc. Victoria, 29 (N.S.), Part II., 1917].

Art. XV.—*On the Age of the Alkali Rocks of Port Cygnet and the D'Entrecasteaux Channel in S.E. Tasmania.*

By PROFESSOR ERNEST W. SKEATS, D.Sc., A.R.C.S., F.G.S.

[Read 14th December, 1916].

Introduction.

The remarkable series of alkali rocks at Port Cygnet, Woodbridge, and other localities on the D'Entrecasteaux Channel, present many features of mineralogical and petrographic interest. They have been made known principally by the researches of Mr. W. H. Twelvetrees, F.G.S., Government Geologist of Tasmania, in a series of papers in which he has described their mineralogical and petrographic characters as shown in the field and under the microscope. He has also discussed the difficult and vexed question of their age. Other geologists and petrologists who have contributed to our knowledge of these rocks include the late Mr. Petterd, the late Professor Rosenbusch, and Dr. F. P. Paul. During a visit to South-East Tasmania in January, 1916, I examined this district. Mr. Twelvetrees was good enough to show me the chief outcrops, and to discuss the problems with me in the field, while Dr. W. N. Benson, of Sydney University, was with us in the earlier part of our stay at Port Cygnet.

This brief paper results from the discovery at Little Oyster Cove, Kettering, of evidence bearing on the vexed question of the age of the alkali series in this part of Tasmania.

Previous Literature.

(1) The earliest reference to the alkali rocks of this area, apart from their approximate distribution as shown on the Geological map in Johnston's Geology of Tasmania, 1888, appears to be a paper by Twelvetrees and Petterd, entitled "On Havyne Trachyte and allied rocks in the districts of Port Cygnet and Oyster Cove. (Proc. Roy. Soc., Tas., 1898-9.)

(2) In the handbook for the Aust. Assoc. for Advancement of Science, Hobart, 1902, Mr. Twelvetrees gave a sketch of the Geology of Tasmania, in which he referred to the elaeolite syenites,

phonolites and trachytes at Port Cygnet (pp. 24, 26 and 27), and tentatively referred them to the top of the Permo-Carboniferous series.

(3) Mr. Twelvetrees, in a paper, entitled "A Geological Excursion to Port Cygnet," in connection with the Australasian Association for the Advancement of Science, 1902, published by Roy. Soc., Tasmania, 1902, in the course of a report on the excursion described the modes of occurrence and petrological characters of the chief rock types then known, including in his report petrographic determinations by Professor Rosenbusch.

(4) Mr. Twelvetrees contributed a "Note on Jacupirangite in Tasmania," to the Roy. Soc., Tasmania, 1902, in which he described the occurrence of this rock among the alkali intrusions of Port Cygnet.

(5) Mr. Twelvetrees, in a paper, entitled "On the Nomenclature and Classification of Igneous Rocks in Tasmania," published by the Aust. Assoc. for Adv. of Science, New Zealand, 1904, pp. 264-305, discussed the position of the alkali series in a review of the classification of the igneous rocks of the State.

(6) Dr. F. P. Paul published a paper, entitled "Foyaitisch-Theralitische Gesteine aus Tasmania," in Min. Petr. Mitt., Vienna, 1906, pp. 269-318, in which he recorded detailed chemical and petrological work among the alkali series.

(7) Mr. Twelvetrees made a "Report on Gold at Port Cygnet and Wheatley's Bay, Huon River," published in Report of Secy. of Mines, Tasmania, 1907, in which he associates the gold occurrence with quartz veins developed in the metamorphosed sediments of Lower Permo-Carboniferous age at the contact with the alkali intrusive rocks.

(8) Mr. Twelvetrees, in his "Outlines of the Geology of Tasmania," published in the Report of the Secretary for Mines for 1908-1909, pp. 133, 141 and 142, regarded as unsettled the precise age of the elaeolite and alkali syenites, with various alkaline porphyries at Port Cygnet and along D'Entrecasteaux Channel, but placed them at the top of the Permo-Carboniferous series in Tasmania, above the horizons of the Southport sandstones and shales, and the Mt. Cygnet and Adventure Bay sandstones and shales, of which the latter is correlated with the Newcastle series of New South Wales. On pp. 141, 142 it is stated that the alkaline rocks which form a S.W., N.E. belt running from the Huon River through Port Cygnet to Woodbridge and Kettering, are referred provision-

ally to the close of this period (Permo-Carboniferous). It is definitely known that they are intrusive into the Lower Marine sandstones and mudstones, and they appear to be cut through by the diabase which is considered to date from the close of the Mesozoic. The belt comprises the following rock varieties:—

Alkali Syenites.—Quartz augite syenite, Aegirine augite syenite, Alkali syenite porphyry.

Elaeolite Syenites.—Pyroxene foyaite, Mica foyaite, Jacupirangite, Amphibole foyaite porphyry, Sölvsbergite porphyry, Mica sölvsbergite, Tinguaite porphyry, Monchiquite nephelinite.

Essexite.—Essexite.

Auriferous quartz and pyrites have been developed near the line of contact of these igneous rocks with the Permo-Carboniferous sediments, and a good deal of alluvial gold has been recovered from the creeks and flats.

(9) Dr. H. I. Jensen, in Proc. Linn. Soc., N.S.W., 1908, pp. 557-558, referring to the rocks of the Port Cygnet group, remarked on their general close resemblance to Australian alkaline rocks, and stated that they were considered without very much evidence to be of Lower Mesozoic age. They are known to be later than the Permo-Carboniferous, and to antedate the Pliocene, but direct evidence to fix their age more closely appears to be wanting.

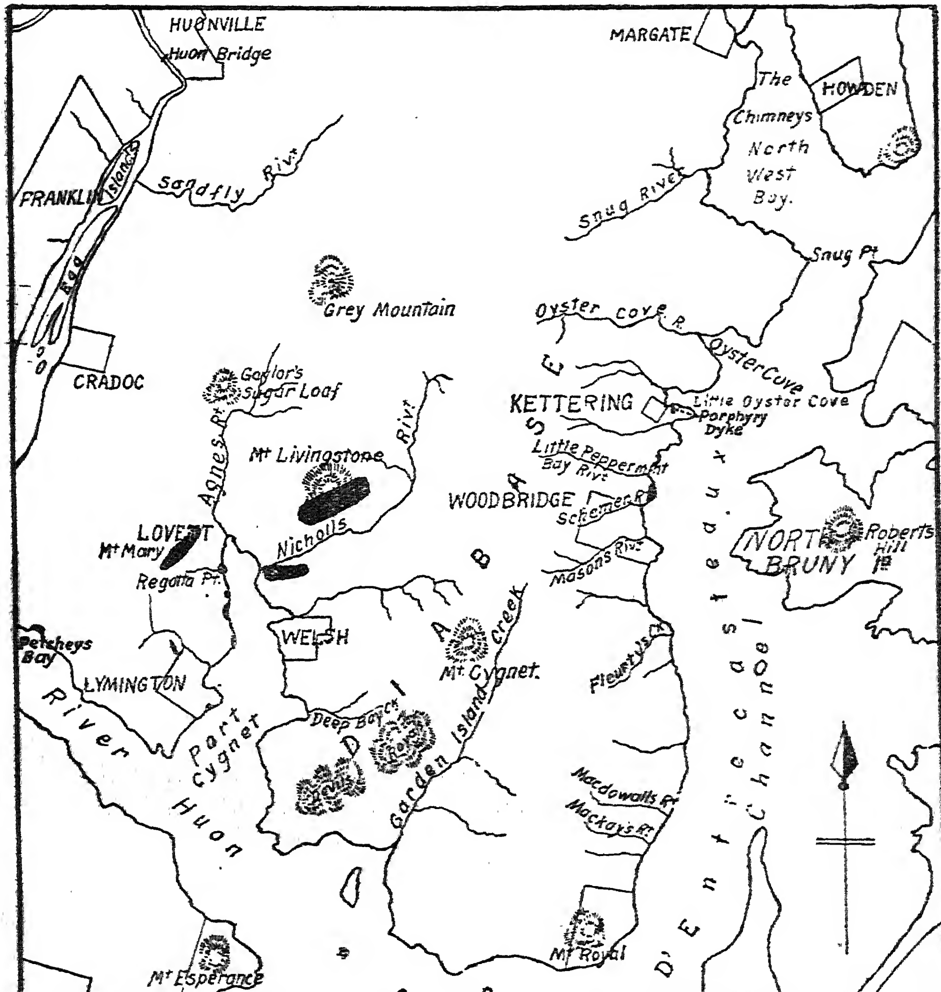
(10) Professor David and the writer wrote a chapter on the igneous rocks in the Geology of the Commonwealth in the Federal Handbook on Australia for the British Association meeting of 1914. On p. 309, under the heading, Jurassic (?) (possibly Triassic), they refer to the foyaitic rocks of the Port Cygnet series. These rocks are considered to be perhaps of Lower Mesozoic age. They are all strongly intrusive into the Permo-Carboniferous series, but their relations to the Jurassic sedimentary rocks and to the diabase have not yet been clearly demonstrated.

Distribution of the Alkali Rocks.

Two groups of outcrops of alkali rocks occur in this district,[1] one in the S.W. of the area on the shores of the Huon River and of Port Cygnet, the other in the N.E. part of the area, on the shores of Peppermint Bay and Little Oyster Cove on D'Entrecasteaux Channel. The exposures of alkali rocks in the first group in the S.W. of the area include the following:—An outcrop in Petchey's Bay on the Huon River, dykes of porphyry at Lymington, a quarter

1 See locality map.

of a mile south of Shag Point on Port Cygnet. N.W. of this is the akerite or quartz augite syenite outcrop, 1½ miles up Forester's



SKETCH MAP OF PORT CYGNET AND KETTERING
S. E. TASMANIA
Alkali Rocks in Black. *Scale of Miles* 0 1 2 3

Rivulet on the back road to Mt. Mary. North of this is the plexus of alkali rocks composing Mt. Mary. East of this on the shores of Port Cygnet are the main outcrops of the much-differentiated alkali-rich rocks of Regatta Point, and various other localities

along the coast southwards for 1½ miles. Stretching inland from the opposite or N.E. shores of Port Cygnet another outcrop of alkali rocks occurs along the Peppermint Bay Road. One mile N.E. of the town of Lovett are the alkali rocks of Livingstone Hill. The second group of alkali rocks occurring in the N.E. of the area consists of the alkali porphyry of Woodbridge towards the northern extremity of Peppermint Bay. Two outcrops occur here, intruding the Permo-Carboniferous sediments. Permo-Carboniferous glacial beds outcrop in Little Peppermint Bay. Further north, on the south side of Little Oyster Cove, diabase, Permo-Caboniferous sediments and alkali porphyry are all represented.

Between these two groups of outcrops in the S.W. and N.E. of the area a gap of 8 or 9 miles occurs, consisting mostly of hilly country, in which up to the present the only rocks known are diabase and Permo-Carboniferous sediments.

I visited all the localities mentioned above under Mr. Twelvetrees' guidance, with the exception of the outcrop in Petchey's Bay, which I have not seen. I am indebted to one of my students, Mr E. O. Cudmore, for specimens of the alkali rock from this locality.

Field Occurrence of the Alkali Rocks.

In all the localities examined the alkali rocks present the characters of intrusive rocks. The petrographic descriptions by Mr. Twelvetrees and by Professor Rosenbusch indicate that so far as textural characters go some of the porphyries, with fine-grained ground-mass, show fluidal and other characters, which occur in lava flows, but since these textures are also represented in dyke rocks and the field relations are generally clear, their intrusive character is practically placed beyond question. Some of the coarser-grained varieties near Regatta Point and the akerite mass on the back road from Lymington to Mt. Mary are described as syenites of various kinds, but they occur as relatively small intrusions, intimately associated with the smaller dykes, and are best regarded as hypabyssal in origin, and described as larger dyke-like masses. In every case except the one presently to be described these rocks have penetrated the Lower Marine series of the Permo-Carboniferous sediments. Junction specimens were obtained from south of Regatta Point, and from Mt. Mary and at the latter place especially the Permo-Carboniferous rocks near the contact are considerably altered. They have been converted into indurated and silicified rocks, more or less pyritized, and have been penetrated

by small quartz veins, which, as Mr. Twelvetrees has described, have shed a fair quantity of gold, since recovered in alluvial workings near by.

The Porphyry Dyke Cutting the Diabase at Kettering.

While the age of the alkali series is thus proved to be post Lower Permo-Carboniferous, its relations to the only other rock of the district, the diabase, have hitherto remained obscure. A ridge of diabase runs down the eastern side of the peninsula formed between the D'Entrecasteaux Channel, Port Cygnet and the Huon River, and on the western part of the peninsula Permo-Carboniferous rocks outcrop at the surface. Although Mr. Twelvetrees and other geologists have made several traverses across this ridge separating the S.W. and the N.E. occurrences of alkali rocks, no members of the alkali series have yet been found in any part of this intervening ridge. Impressed by this negative observation Mr. Twelvetrees has explained it on the supposition that the alkali rocks are older than the diabase.

In the latter part of our visit Mr. Twelvetrees and I worked northwards from the alkali outcrops at Woodbridge on the north edge of Peppermint Bay, past the Permo-Carboniferous glacial deposits of Little Peppermint Bay to Little Oyster Cove at Kettering.

On the south side of Little Oyster Cove, going east for about 150 yards beyond the jetty, we found the diabase came down to the shore. At this point a low outcrop, a few feet in height, occurs, and an abrupt change from diabase to alkali porphyry was observed. The porphyry extends for 15 to 20 feet, and then just as abruptly diabase comes in again, and remains nearly to the east extremity of the bay, which is occupied by Permo-Carboniferous sediments, while on rounding the point to the south diabase comes in again.

There is no doubt in my mind that the occurrence of Porphyry with parallel walls and in abrupt contact with the diabase represents an intrusion of porphyry into the diabase. The only alternative explanation of the relations of the two rocks that occurs to me is that of a large mass of porphyry detached by and included in the diabase. I reject the latter explanation, and adhere to the view that the porphyry is part of a dyke for two reasons. The first is that although the exposure is limited, one can see that the walls in contact with the diabase are parallel as one would expect to find in a dyke. The second reason is that at the contact with

the diabase the porphyry for about half-an-inch in width is quite different in texture from the central part of the mass. The small porphyritic crystals are set in an exceedingly fine-grained paste or ground-mass, much finer in texture than the normal ground-mass, away from the contact. This feature I regard as a selvage to the dyke produced by the rapid chilling of the intrusive mass against the cold diabase walls.

Kainozoic Age of the Porphyry Dyke at Kettering.

The above evidence, I think, establishes the conclusion that the prophyry at Kettering is a dyke, intrusive into the diabase, and therefore younger than it. The age of the diabase sills in Tasmania has been demonstrated to be post Upper Jurassic, since in several places an intrusive contact with these sediments has been established. It is generally believed to be probably Cretaceous in age, and to have been intruded during the earth movements, which led to the breaking up of the Gondwanaland continental mass or masses.

If this view is correct the porphyry dyke at Kettering is probably post-Cretaceous in age, and in that case belongs to some part of the Kainozoic period.

Relations of the Kettering Dyke to the other Alkali Rocks of the District.

While the field evidence as described above defines the age of the Kettering dyke as post-Diabase, and therefore almost certainly Kainozoic, the field relations of the other alkali occurrences in the district only enable one to assert definitely that they are post-Lower Permo-Carboniferous.

We must turn to petrographic evidence to see whether or no there are sufficient petrographical and mineralogical resemblances between the various members of the suite of rocks to make it probable that they were all intruded during the same period.

For this purpose I have had a number of sections cut of rocks from the various localities mentioned above. This paper is not concerned with the detailed microscopic characters of the rocks, and my examination of the sections has simply been for the purpose of correlation of the various dyke occurrences.

Examination in the field or by hand specimens suggested that as far as naked eye examination goes the rocks which most closely resembled the Kettering dyke occur at Woodbridge and at Petchey's

Bay, the latter being the outcrop furthest to the S.W., the Kettering dyke the outcrop furthest to the N.E. in the area examined.

Microscopic Characters of the Alkali Porphyries.

A section kindly lent me by Mr. Twelvetrees, labelled Foyaite porphyry, Little Oyster Cove, contains as phenocrysts, dark-green pleochroic hornblende, pale-green augite in smaller prismatic crystals, plagioclase and small crystals of sphene. The ground-mass consists of small rectangular crystals of alkali felspar.

A section from the central part of the dyke at Kettering, Little Oyster Cove, shows that the rock has been considerably altered by weathering. The phenocrysts consist of Hornblende, more or less completely altered to aggregates of micaceous and chloritic material, altered plagioclase, with a ground-mass of small rectangular crystals of alkali felspar. Another section of the same rock at the contact with the diabase shows a definite, fine-grained selvage, consisting of a dense felspathic ground-mass, in which are set fairly fresh phenocrysts of plagioclase, and somewhat altered green hornblende. The hornblende in this rock is probably a soda hornblende, and the abundance of felspar, particularly of the alkali felspar of the ground-mass, shows that it is an alkali porphyry of intermediate composition. Somewhat noteworthy is the abundance of plagioclase phenocrysts.

With this rock may be compared those from Woodbridge and from Petchey's Bay. The Woodbridge rock in section shows as phenocrysts dark-green hornblende, pale-green alkali-augite, abundant plagioclase, and small sphenes set in a ground-mass of rectangular alkali felspars.

The Petchey's Bay porphyry in section has large phenocrysts of plagioclase, some of which may be anorthoclase, green aegirine-augite, and small sphenes in a ground-mass of rectangular alkali felspars.

There can be no doubt of the great general similarity of these three rocks. In each, the same ground-mass of alkali felspar is present, and the plagioclase phenocrysts predominate. Probably the Petchey's Bay rock, owing to the abundance of aegirine-augite is the most highly alkalic, the Woodbridge rock intermediate in alkali content, and the Kettering dyke somewhat less alkalic. Among the Port Cygnet rocks occur many whose texture and composition differs considerably from these three described above, but in the series near Port Cygnet various alkali porphyries are present

in such close field relations to the other types as to suggest strongly a genetic resemblance and reference to the same period of igneous activity.

One of the Port Cygnet porphyries in section shows as phenocrysts big crystals of orthoclase or sanidiare, green aegirine-augite, a little green hornblende, and small sphenes. In the ground-mass occur needles of pale augite, and the rest consists of lath-shaped and irregular alkali felspars, and probably some nepheline, and a very little plagioclase. This rock is distinctly more alkalic than the Kettering dyke or the Woodbridge and Petchey's Bay rocks, and yet in its texture and mineral content, allowing for greater alkali content, family resemblances are to be traced.

It would appear that all the rocks of the district are consanguineous and members of one petrographic province. But it is equally clear that differentiation was developed further in the Port Cygnet and Regatta Point areas than in the more outlying districts of Petchey's Bay in the S.W., and Woodbridge and Kettering in the N.E. This is evident from the fact that while some of the porphyries of the Port Cygnet area are in many respects allied to the Kettering, Woodbridge and Petchey's Bay rocks, there are also present in the central area, as Mr. Twelvetrees has described, adjoining and related rocks in which the mutually incompatible minerals, quartz and nepheline, are separately developed. This close association in the field of quartz-bearing augite syenites and related quartz-bearing rocks with others containing the felspathoids, nepheline and nosean or havyn, provides an interesting example of what are probably nearly extreme types of differentiation in a magma of moderately alkalic character. The rocks of Kettering, Woodbridge and Petchey's Bay probably represent products intruded in a less differentiated form, and may quite possibly approximate in composition to the parent magma.

Comparison of the Alkali Rocks of S.E. Tasmania with other Australasian Types.

Hitherto the question of the age of these alkali rocks has been discussed, firstly, in the light of field evidence, particularly the evidence of the dyke at Kettering, and, secondly, on the evidence submitted that all the rocks of the area are consanguineous, and belong to one petrographic province, and, therefore, probably to one period of igneous activity. A third method of enquiry turns on the evidence of age and of character of the principal alkali

rocks of Australasia generally. Dr. Jensen,[1] among others, has discussed this problem. The age of some of the alkali rocks of Australasia is not yet susceptible of exact determination, since they only come into relation with and intrude rocks of high antiquity. Many were referred by Dr. Jensen to the Eocene period in New South Wales and Queensland, on somewhat slender evidence. The alkali rocks of New Zealand, described by Professor Marshall and others, are referred generally to the middle or upper part of the Kainozoic, and those of Victoria so far as known appear to belong to the period immediately preceding the newer basalts; that is, to the Mid-Kainozoic or the lower part of the Upper Kainozoic.

Some years ago, in a paper on the Volcanic Rocks of Victoria,[2] I tentatively included among Palaeozoic volcanic rocks certain alkali rocks in Eastern Victoria. This reference was based on Dr. Howitt's observations. Since then I have visited some of these districts in the field, and have been impressed by their recent looking characters, and now believe that they are probably of Middle to Upper Kainozoic age. The Mittagong-Bowral series of alkali rocks in New South Wales intrudes the Triassic sediments, and may well be Kainozoic in age. They are interesting in this connection, since they probably come nearest in chemical and mineralogical characters to the rocks of Port Cygnet, as they include syenites allied to bostonite, and aegirine-arfvedsonite-quartz-trachytes. The only alkali rocks in Australia definitely proved to be Palaeozoic in age are the series of alkaline eruptive rocks of the Cambewarra-Kiama districts, south of Sydney. These rocks consist mainly of lavas and tuffs, partly contemporaneous with the Upper Marine series of the Permo-Carboniferous, and partly with the Bulli coal measures. Their petrographic and chemical characters are, however, quite distinct from other alkali rocks in Australia, so far as known, and from the rocks of Port Cygnet, as they contain generally a good deal of potash, and are described as Orthoclase-basalts.

Apart from these Orthoclase-basalts of exceptional characters, it will be noted that other occurrences of alkali rocks intrude various members of the mesozoic, and may, therefore, be of Kainozoic age, while a considerable number are definitely known, not only to be of Kainozoic age, but to be not older than the Mid-Kainozoic. So far as analogy with other Australasian occurrences go it is in favour

1 Proc. Linn. Soc. N.S.W., 1908.

2 Aust. Assoc. Adv. of Sc., Brisbane, 1909. Pres. Add. to Sect. C.

of the view that the alkali rocks of the Port Cygnet and associated areas belong to the Kainozoic period. Objection may be raised that some of the Port Cygnet rocks are very decomposed, and a claim to greater age for them may be made on that account. While, however, some of the rocks are considerably altered so far as the surface outcrops are concerned, which alone are available for examination, fresh material from some of the rock types clearly related to the decomposed rocks can be obtained, and in any case arguments based on relative surface decomposition carry little weight when it is remembered that highly alkalic rocks are more susceptible generally of ready decomposition, and it is usually types richest in the alkalies which show the greatest change.

Conclusions.

The evidence presented in this paper warrants, in my belief, a revision of the previous view that the alkali rocks of the Port Cygnet district are of pre-diabase age, and probably belong to the top of the Permo-Carboniferous series, and it is here considered to be highly probable, if not definitely proved, that the alkali rocks are of Kainozoic age. The most powerful argument adduced is the field evidence of the intrusion of a dyke of alkali porphyry into the diabase (probably Cretaceous in age) at Little Oyster Cove, Kettering. Secondly, the close similarity of the Kettering rock with those of Woodbridge and Petchey's Bay is advanced, and the general similarity with some of the Port Cygnet rocks is pointed out. This leads to the second and more general conclusion, that between all the alkali rocks of the area consanguinity exists, arguing intrusion during a single period of igneous activity. A subsidiary argument, to reinforce the view of the Kainozoic age of the series, consists in a consideration of the age and nature of the alkali rocks of Australasia generally, wherein it is shown that such rocks as are fairly comparable in composition with the Port Cygnet series, and whose age is susceptible of anything approaching precise determination, have been shown to belong to the Kainozoic period. On these three grounds it is claimed that the alkali-porphyry of Kettering in particular and the alkali rocks of the district in general can be referred to the Kainozoic period with a high degree of probability.

[Proc. Roy. Soc. Victoria, 29 (N.S.), Part II., 1917].

Art. XVI.—*Teratological Notes: Part 2.*

By A. D. HARDY, F.L.S.
(State Forests Department, Melbourne).

(With Plates XI., XII., XIII.).

[Read 14th December, 1916].

The first part of this series was devoted to seedlings. The present contribution is intended to record some instances of aberration of stem, branch, and fruit. For part 3 is reserved a number of cases of foliar abnormality.

Root.

One abnormal root arrangement was near Heidelberg, on the Yarra, where erosion of the river bank caused an exposure of the roots of two small red-gum trees (*Eucalyptus rostrata*). The trees, nearly equal in size, stood 8 feet apart, and were connected by a simple cable root. The cable was dead and much waterworn, its thickness varying irregularly between 2 and 3 inches. Seen from a canoe in a swift current by Mr. R. A. Keble and myself, it was not conveniently situated for photography or for further investigation than to note that there was no suture indicative of fusion. It is possible that one of the two trees was originally a sucker of the other, but of faster subsequent development, and that the continuation of the supporting root had disappeared without leaving superficial evidence of its having existed. The specimen was carried away during further erosion, but there is another—though not so good—at a bend of the river just above Heidelberg.

Stem.

Malposition.—Peculiarities in form and posture of the stem may be seen where, on the northern edge of the plains to the north and north-west of Melbourne, the eucalypts (*E. rostrata*) have yielded to the pressure of the prevailing winds of their youth. The southward leaning of about 60 per cent. of these large trees can be seen from the Whittlesea railway. They are bent from the vertical, near the base, through angles varying up to 65 degrees, and at times are so much curved and arched that the large branches have fractured in contact with the ground, and occasionally from this semi-recumbent position send up shoots, or adjust existing shoots, the

inclination of which does not suggest that the winds prevail now in the same force.

Adhesion.—Near Turritable Creek, Macedon, there is a composite growth, comprising two species—*Eucalyptus obliqua* and *E. viminalis*—which by mutual pressure are fused at the base, but have the remainder of their stems and their branches free. In stem and canopy the small Messmate (*E. obliqua*) is dominant, its partner being dwarfed, low-branched, and distorted. The presence of two species would have escaped notice but for the cortical distinction.

Torsion.—Spiral growth, betrayed by the bark, affects many forest trees. When present in species of the cortical group Rhytophloiae, it is conspicuous at all seasons, but, in those of the Leiophloiae, more conspicuous during certain stages of decortication. In the messmates, stringybarks, and silvertop-ironbark, the spiralling of the bark is frequently noticeable, and often, in a mixed forest, *E. sieberiana* may be singled out from amongst others of somewhat similar appearance, because of this spiral tendency. Of the Leiophloiae there is a tree between Lara and the You Yangs, which, when alive, had dark and light slashes of colour markings, irregular in detail, but of general spiral trend. The picture shown is from a photograph taken after the death of the tree, when ringbarked, the conspicuous, irregularly sinuous and spiral lines indicating the openings in the bark due to shrinkage.

Bifurcation.—Early forking of lowland trees is not uncommon. The tendency of trees (of lofty habit in the highland glens) to dwarf, and approach the shrub form in exposed lowland situations may be seen in *Eucalyptus viminalis* and *E. obliqua*, while in the silurian hills of Kerry, *E. obliqua* and *E. amygdalina* have many stems arising from near the ground, and resembling "mallee" or shrubby Eucalypts. There is a young *E. rostrata*, symmetrically bifurcated, in Richmond Park, Melbourne. The giant Eucalypt *E. regnans*, occasionally forks early in sheltered localities.

Fasciation.—This phenomenon is, according to Blaringhem and Worsdell, the result not of the union of younger organs which remain coherent for a longer or shorter period, but from the absence of individualization of the cells or tissue into independent buds. Worsdell attributes fasciation to congenital impulse, and not to post-genital union of parts, as supposed by Masters and others, and regards it as the first sign of partition of a single shoot.

In the practically aphyllous Exocarpi and Casuarinae fasciation may be found. *E. cupressiformis* exhibits the formation frequently

in the terminal branches. I have seen it in *E. spartea* only once, and the specimen of *E. gracilis* (exhibited) is the only case of fasciation of this sub-desert species known to me or to the many travellers in the Mallee region, whom I consulted. The specimen was sent by Mr. Poole, Staff Surveyor, as a novelty from North-West Victoria. The shrub is affected from within a few inches of the ground upwards, until, towards the summit, multiple forking takes place, and this is accompanied by curling, an almost regular concomitant of fasciation. Small branches arising from any part of this fasciated axis are normal in character.

A fasciated branch of *Casuarina stricta* was exhibited[1] at a meeting of the Field Naturalists' Club by the Assistant Director of the Botanic Gardens, Melbourne.

The great length to which fasciation may affect an axis is seen in the specimen of Tecoma (exhibited), which is flattened through four feet of its length.

Branch.

Cohesion of Branches.—Cohesion of contemporary or other branches of one plant occurs in *Eucalyptus rostrata*, the crooked branching of which affords more opportunities than are obtained in any other species. The tree figured (Plate XI.) is growing in the Kiewa Valley, near Tanganbalanga. There is fusion of branches in several places, the primary cause being the premature forking of the stem at 4 feet from the ground. This early bifurcation of the axis allowed insufficient room for subsequent branching of the great divisions, which are 2 feet thick; so the secondary branches came into contact, and, by mutual pressure, have fused. At one place the smaller branch became so overgrown by the bark of the larger as to produce the appearance of penetration. Another example of branch fusion was described by a member of the National Herbarium staff, and figured in the "Victorian Naturalist."[2]

Torsion of Branches.—This is a rare occurrence where uncultivated plants are concerned. Plate XI., fig. 2, shows two of the many affected twigs of one tree—*Casuarina stricta*—near Melbourne. In general appearance the tree was as healthy as its neighbours, none of which was similarly torsive, but it and others succumbed to the ravages of borers. Both vegetative and reproductive twigs were affected, the spiral being short in proportion to the total

1 Pitcher, Vict. Nat., xxix., Jan., 1913.
2 Audas, Vict. Nat., xxvii. (1911) p. 207.

length—from a tenth to a twentieth part. In many twigs the spiral growth was at or near the base, in some others about midway, and in a few the terminal node was the abnormal one. In Casuarina the staminiferous twigs have the stamens at the nodes of the apical end only, but in the abnormal twigs a spiral staminiferous node was in one case succeeded by several nodes of purely vegetative character. Staminiferous spirals were usually terminal, and the anthers and their pollen grains were morphologically good; so, too, were the stamens borne at terminal nodes of twigs affected by torsion nearer the base. The method of growth of these spirals appears to be as follows:—Instead of the usual production of whorls of leaves, which in the matured branchlets might reach an inch or more in length—laterally connate and decurrent except for the scale-like free end which forms the cup whence springs the succeeding shoot—there is, usually, in the abnormal branchlets a bursting of the cup-like circlet of scales, and an oblique emergence of a laterally-developing spiral band, forming a tortuous structure with laterally connate members, each of which is terminated by a pointed, scale-like leaf-end, similar to those of a normal whorl. The leaves laterally connate in such a laterally winding spiral are one-fourth the length of normal branchlets, and in number may be regarded as indefinite, there being 45, 51, and 59 respectively in three of the longer spirals which I closely examined; and other spirals were longer. The spirals wound indifferently to the right or to the left in respective twigs. The stamens in the case of a staminiferous spiral appeared as a continuous fringe at the overlapping edge of the imbricated tunic so formed. The number of leaf-ends in a whorl in *C. stricta* is not constant, but is from 9 to 12.

In many aquatic or marsh plants torsion of vegetative shoots which are normally cylindrical and hollow is a not uncommon occurrence. *Heleocharis sphacelata* is one that I have frequently noticed, and in this case the discoid septae become ellipsoid. The cylindrical shoot becomes flattened, and twists in a more or less easy torsion while keeping perfectly straight (the twist being that of an auger rather than that of a corkscrew), while, in other plants, solid, angular shoots may twist through an inch or two of the apical end, the twist being a compromise between a zig-zag (in one plane) and a corkscrew spiral. This is exemplified by the shoots of *Xanthorrhoea minor* (Plate XIII., fig. 5), the leaves, straight for about 12 inches, having the terminal inch torsive.

Heterotropy (reversed direction of growth of a branch and branchlets of a hybrid eucalypt. Plate XII.).

On the way from Stawell to the Grampians, and near Brigg's Creek, on Rose's Gap road, there is, in a paddock lately occupied by Mr. Wills as a bee farm and range, a tree which seemed to be a hybrid (*Eucalyptus hemiphloia* × *E. melliodora*), with foliage, fruit and bark satisfying the requirements of the former, and with buds distinctly nearer the latter species. Both species grew in the district, but with no *E. melliodora* lately in the immediate neighbourhood. *E. melliodora* (Yellow Box) sometimes—frequently in the silurian country near Alexandra, etc.—assumes a drooping habit like *Salix babylonica*, or the Weeping Elm; many trees may be found aggregated in a locality or scattered amongst those of more or less erect habit, but *E. hemiphloia* avoids this weeping habit entirely, so far as my experience goes. In the particular tree under notice, there is a fork in the stem at only a few feet from the ground, and at a height at about 30 feet an offshoot from the main limb bears a branch which terminates abruptly, but sends back at an angle of 40 degrees or so a smaller branch, which, by reason of its slenderness and the weight of foliage subsequently produced below, hangs vertically. After 10 feet of growth earthwards, during which there were several abortive attempts to retain downward-growing twigs, one lateral branch at an acute angle grew downwards until at about 6 feet it sent a branchlet upwards at an acute angle, and this persisted, and bore good foliage, and the downward growth ceased and withered back to an abrupt end, where the dead portion snapped off. Meanwhile the leader pursued its downward course, the stumps of dead and missing twigs indicating the production of several downward branches—leaving a space of about 16 feet of denuded axis below, while three branches have persisted, and from these latter I collected the bloom, buds and fruit by which I recognized the probability of the parentage being as above mentioned. At the abrupt, broken, and dead termination of this 30-feet-long pendent leader a final branch, directed upwards at an acute angle, bore abundant foliage. The whole, swinging from 30 feet above, swayed and gently gyrated in the light breeze, but during a gale must be badly used at times. The drooping habit of one branch and some offshoots reminded me of weeping forms of *E. melliodora*, and if the tree is, as I believe, a hybrid, it may be that the tendencies to an erect—and also to a drooping—habit were present at the same time during growth, with the heterotropic result shown in

the drawing. The leader, instead of tapering downwards, thickens considerably before—or because of—upward branching. Evidence of many attempts to produce persistent geotropic offshoots is seen in the numerous "die-backs," some of which are shown in the plate (XII., figs. 1-7).

Adventitious Shoots.—These are commonly seen in many species of eucalypts, but they are generally vegetative growths caused by injury to the old stem or branch. In those species, which have juvenile and adult foliage distinct, e.g., *globulus*, *goniocalyx*, *elaeophora*, *viminalis*, *rubida*, *stuartiana*, and many others, the adventitious shoots exhibit the characteristic phyllotaxis and axial nature of juvenile shoots, but the case now brought under notice (Pl. XIII., 4) is of unusual interest in that these shoots, taken from the fork of a cultivated Blue Gum (*E. globulus*) at Stawell, has an abundance of buds, flowers, and fruit in the axils of the opposite, sessile, dorsiventral leaves. Springing from the same affected spot, and well shaded by the canopy of mature foliage, were several other similar shoots. The tree was generally in bloom or bearing young buds or fruits, but in no case did any of the normal branches carry more fruit than these "reversionary" shoots. In the Stawell district, I found trees of *E. elaeophora* in which there were buds, flowers, or fruit in the axils of dorsiventral, opposite, sessile leaves, and also where the leaves were opposite, but petiolate, and mostly on drooping branches at a height of 12 feet or so. (Pl. XIII., 1.)

Eucalyptus dives[1] is known to bloom while in the sucker stage, and it is not uncommon to find, in the axils of both opposite, sessile leaves of the lower branches and petiolate alternate leaves higher on the sapling, flowers or fruit in various stages of development; but the limit of precocity seems to have been approached, if not reached, in a sucker shoot (exhibited) taken from the base, at the ground, of a sapling of *E. dives*, near Healesville. This shoot, with sessile, opposite, dorsiventral leaves has a well-developed umbel in an axil at the second node, six inches from the ground, and again at 12 inches, the total length of the shoot being 18 inches. In *Eucalyptus rostrata*, usually a large tree and one that does not bloom in the sapling stage, we may find in exceptional circumstances a similar precocity. The species grows straight-stemmed and robust on damp flats, subject to periodical inundation, but, as the photograph (exhibited) shows, may also thrive on rocky ground well above

1 At maturity this species is a forest tree in good localities.

the limit of stream influence, while yet obtaining large size, the rooting being good. On the Hawthorn bank of the Barker's Road tram cutting, near the Yarra, there are two shrubby specimens of *E. rostrata*, which bloom generously every year; the leaves, flowers, and fruit are typical, but the buds often bear conical opercula. These lowly specimens, growing as they are on the outcropping silurian strata, which dips at an angle of about 70 degrees, must have their roots confined to the bed planes. Yet on comparatively unfriendly ground, with roots unusually confined, and the general habit altered, they produce abundant fruit, some of which may be on branches only two feet from the ground. One of the plants is 12 feet, and the other 6 feet, high.

Fruit.

Bifurcated Peduncles.—Bifurcated peduncles, or, alternatively, double umbels are rare. The specimens shown (Pl. XIII., 1) is from a branch of *E. elaeophora* collected at Stawell. There were many adventitious shoots on the upper branches of the tree whence the specimen was taken, and it appears to be in transition stage, the phyllotaxis being that of the juvenile plant, near the base, and up to the middle, while towards the apex the leaves become alternate and petiolate, though lacking the length of those of adult foliage. Near the middle of the twig are a pair of opposite leaves, with petioles much longer than even those of the normally petiolate leaves of the species, and in the axil of each there is a double umbel. Although the reduced number of fruits suggests bifurcation of the peduncle of a single umbel, I prefer to regard it as a case of proliferation, as the umbels in normal axils on this tree were in many places sparsely fruited, and in each of the affected axils there was one peduncle longer than the other. Normally there should be in the axils of the alternate petiolate leaves, simple pedunculate umbels, each of which should have six fruits. It will be observed that these two long-petiolate leaves are abnormally narrow; they are narrower than any I have seen on a tree of this species. I have seen double umbels, also in *E. goniocalyx*, *E. elaeophora*, and *E. obliqua*.

Connation.—Lateral connation of fruits or even syncarpy might reasonably be expected in some species of eucalypts, owing to there being many almost stalkless fruits forming the umbel, or where short-stalked fruits are few but large, as in *E. globulus*, etc., but the occurrence is rare. Irregularity of shape through mutual

pressure may sometimes be seen. Sustained pressure is at times avoided by the sacrifice of one or more members of the umbel. In a quantity of fruit of *E. cordata*, procured from Tasmania by the Conservator of Forests, Mr. H. Mackay, I found fully 25 per cent. of the umbels—which usually are trimerous in series monoplane or approaching thereto—affected by lateral connation. In these coherent fruits the rims were circular or nearly so. The cohesion was not necessarily due to mutual pressure, but probably congenital, as in some cases there were only two fruits occupying the axial place of three. (Pl. XIII., 3.)

Precocious Fruiting Amongst Resting Buds.—This was observed in two umbels of *Eucalyptus eugenioides*. It is the habit of many eucalypts to rest from flowering during a season, and to bloom in alternate years. In some species the bud-to-seed period is a few months—in others one, two, or (rarely) perhaps three years. *E. rostrata* is prone to biennial fruiting; in some species a season of vigorous reproduction is sometimes followed by two years' rest. This phenomenon (the "on" and the "off" year) is watched carefully by apiarists as of ecomonic importance in their anticipation of, and arrangements for, "honey-flow." Other eucalypts, as the winter-flowering *E. leucoxylon*, *E. sideroxylon*, etc., bloom yearly; and others, climatically affected, are irregular, but in most cases the fruit does not mature until the second year. So that, as a rule, a fruitful eucalypt bears either young fruit which will ripen next year, or old fruit of last year's flowering, or may have the old fruits present during the early development of young fruits of the present season. The habit of *E. eugenioides* is not known to me, but of four twigs collected between Bruthen and Orbost one bore two umbels of abnormal development. Of these one comprised seven young flowers and one old fruit, while the other consisted of six buds, one newly expanded flower, and two fully matured fruits. In view of the resting condition of the contemporary buds at the time when these fruits began to develop in the previous year, this may be regarded as a case of precocity. (Pl. XIII., 2.) Seen also in *E. obliqua*.

Delayed Dehiscence.—Species of both *Callistemon*[1] and *Melaleuca* retain their ripened seeds for years. The specimen of *C. lanceolatus* (exhibited) accounts for six years' fruit, and seeds from the first four of the series germinated when the capsules were opened by artificial heating.

1 Cf. Ewart, Annals of Botany, vol. xxi., 1907, 135.

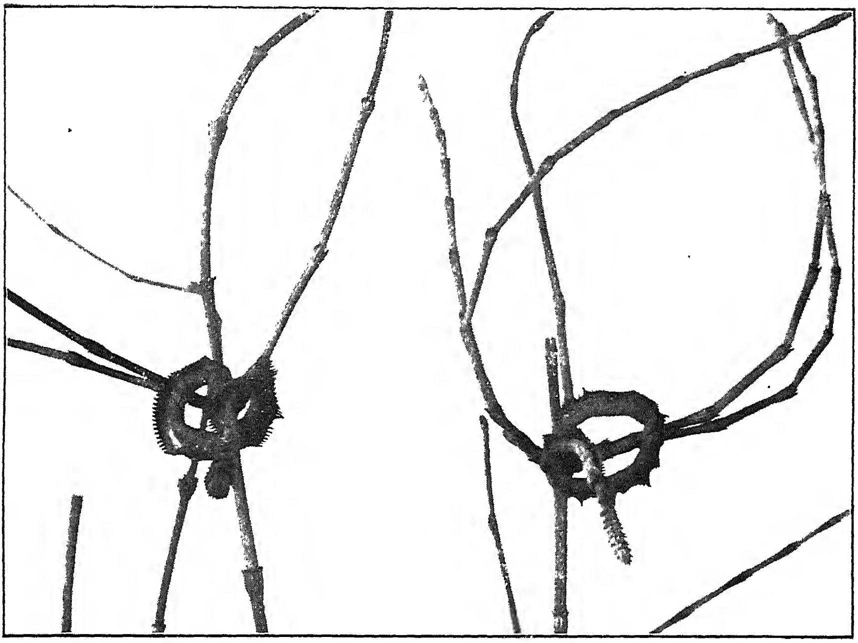
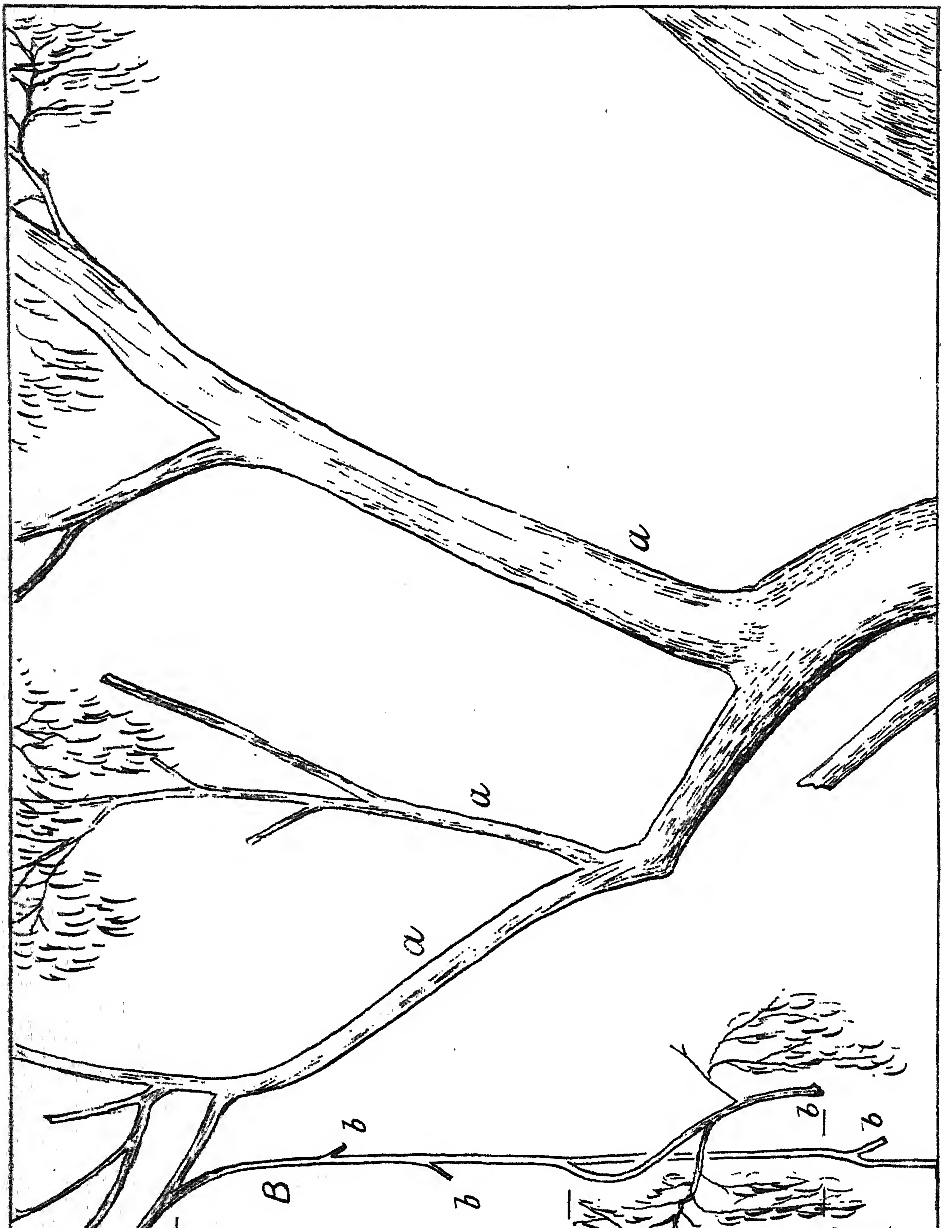


Fig. 2

Fig. 1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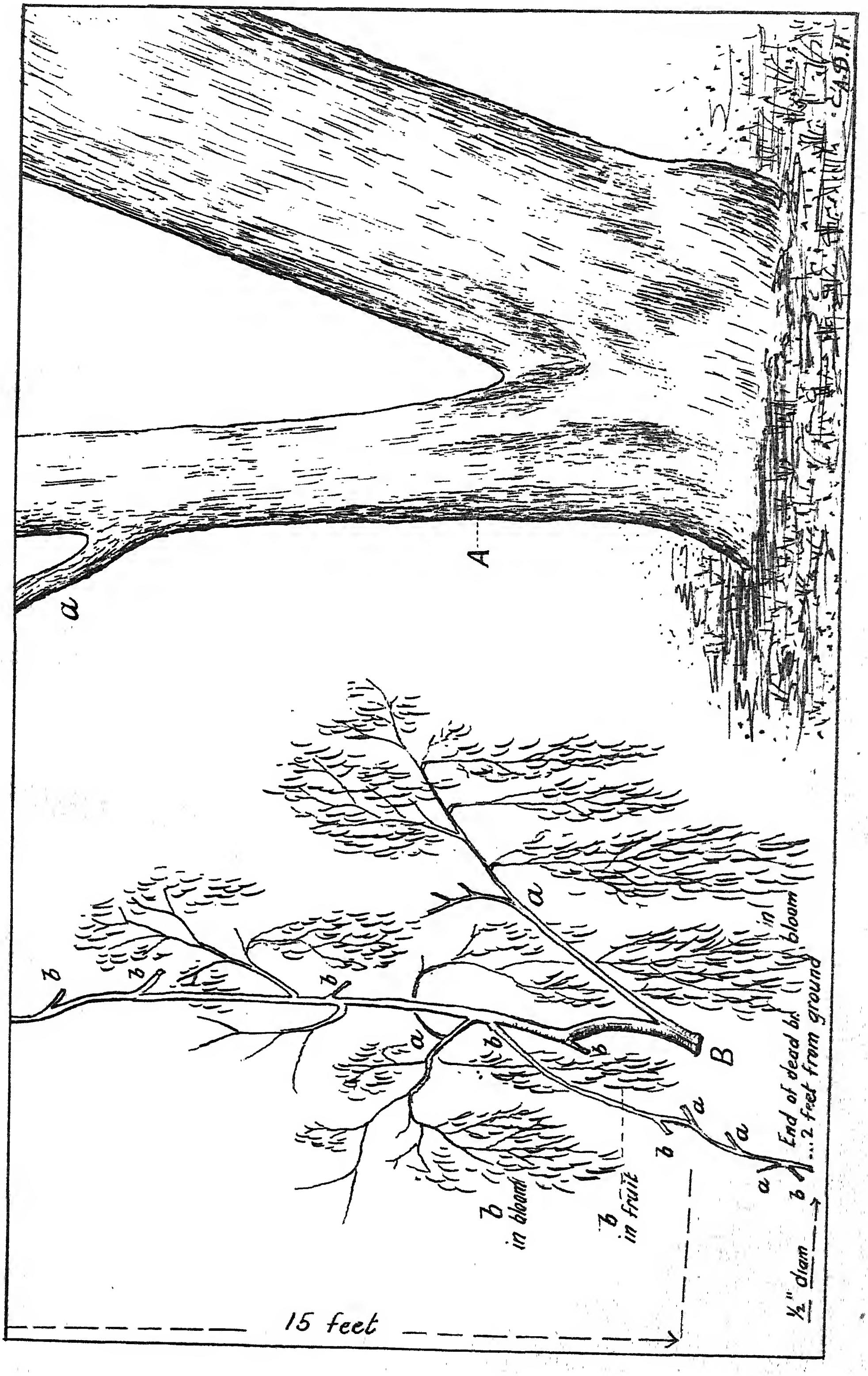
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b
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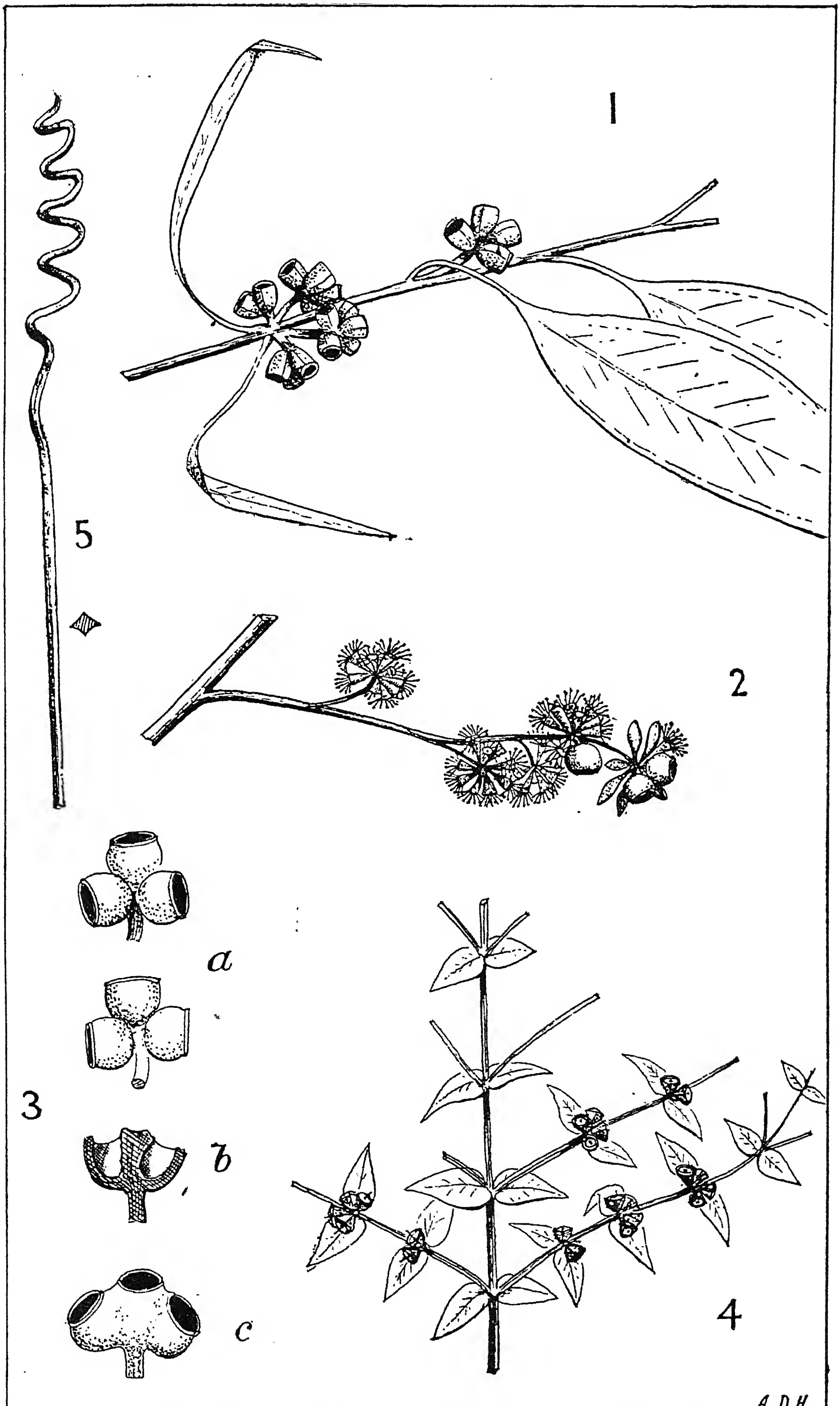
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DESCRIPTION OF PLATES.

Plate XI.

Fig 1.—*Eucalyptus rostrata* Schl., showing fusion of branches.

2.—*Casuarina stricta*, Aiton (Syn. C. quadrivalvis, exhibiting spiral torsion).

Plate XII.

Sketch (somewhat diagrammatic) of part of a Eucalypt, probably (*E. hemiphloia*, F.V.M., × *E. melliodora*, Cunn.), the pendant branch 30 feet long, exhibiting heterotropy. Upward growths A, a, a; downward growth, B, b, b, b.

Plate XIII.

Fig 1.—*Eucalyptus elaeophora*, F.V.M. A twig showing proliferation associated with heterotaxis. ($\frac{1}{2}$.)

2.—*E. eugenioides*, Sieber, with precocious fruits in two umbels, developed a year in advance. ($\frac{3}{4}$.)

3.—*E. cordata*.

(a) Two normal umbels.

(c) One of many umbels with fruits laterally connate.

(b) Section showing two fruits connate. (Nat. size.)

4.—*E. globulus*, Labill. An adventitious shoot, with reversionary foliage, and fructiferous. Rough sketch of part only of one of several shoots. (Photograph exhibited.)

5.—*Xanthorrhoea minor*, R. Br. One of many torsive leaves, the whole plant being affected. (Nat. size.)

INDEX.

The names of new genera and species are printed in italics.

END OF VOLUME XXIX.

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THE AUTHORS OF THE SEVERAL PAPERS ARE INDIVIDUALLY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN.

MELBOURNE:

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[Proc. Roy. Soc Victoria 30 (N.S), Part I, 1917]

Art. I.—*Timber Production and Growth Curves in the Mountain Ash (Eucalyptus regnans).*

By R. T. PATTON.

(With Plates I.–II.)

[Read April 12th, 1917].

It has been said that Mountain Ash will mature in 40 years, and will give in this time a butt of from 2 ft. to 2 ft. 6 in. It has also been claimed for Mountain Ash that it is the fastest growing tree in the world, and that it will give a cut of 150,000 ft. super per acre. In order to test the truth of these statements a series of measurements was carried out at Powelltown on logs of this timber.

It was found impossible at the time to get any reliable figures as to either its fast growing rate or its quantity of timber per acre. Many factors militated against this. In the first place all the forest now being cut is over ripe, and consequently many trees are hollow. Again, a very large number of trees have incipient decay in the heart. Other factors also prevented any accurate estimate being formed. However, there was ample material for a study of the annual rings. It was impossible to obtain measurements from all logs coming in, as in quite a large percentage there was either a pipe, or decay had proceeded far enough to destroy the boundaries of the first annual rings. Only those logs, then, were taken in which the annual rings were clearly defined. The measurements were taken to the eightieth (80th) ring, and not continued further owing to the difficulty in many cases of distinguishing the rings. In one case the rings, though narrow, were easily distinguishable to the 125th ring. It was obvious from these later rings that the tree had lacked vigour. This was borne out by a study of the trees in the standing forest. The paucity of foliage on these big trees is very noticeable, as was also the amount of mistletoe. No mistletoe was observed on the saplings or even on trees half grown. From these observations, one was led to conclude that the tree reaches its prime well under a hundred years.

The most remarkable feature is the rapid expansion of the trunk (and hence width of annual ring) during the first ten years of growth. This is shown in Fig: 1. In this graph the average width of ring for each decade is shown. The annual rings were measured in groups of ten and then averaged. This was done in order to

allow for the variation of the successive seasons, conditions of environment, and any accidents. Some very wide fluctuations were obtained. but these were discarded as being obviously not the normal growth of the tree. On reference to Fig. 1 it will be seen that there is a steady decline in the width of the ring. It is very apparent, too, that the width varies much less after the 30th year. This rapid decrease to the 30th year, and then a more gradual decrease after that, may indicate that the tree is entering on its manhood, so to speak. The theoretical curve which has been drawn indicates that it will approach the abscissa very gradually, and this is what we would expect.

The differences between the width of the annual rings as the tree gets older will be less and less. There is a point of interest here, and that is that the enormous decrease in the width of the ring may be due to overcrowding, or putting it in other words, that as the trees grow older and so many are striving for the same light and carbon dioxide, that the crown it not as large as it would be if the forest were controlled. It was very apparent from a study of the mature trees that width of ring is largely dependent on the distance of the trees apart, for in many logs the original centre is well to one side of the mature log. Some trees have limbs on the congested side only 6 to 8 ft. long, while on the free side they are 15 to 20 ft. long. The maintenance of a good head is important from a forestral point of view.

In Fig. 2 the curve is given for the diameter at each decade. The curve is remarkably even, and from it one may deduce the age of a tree very approximately if the diameter (or girth) be known.

It will be seen on inspection that the curve is flattening considerably at the 80th year, and this again indicates that the tree is making very little headway. The curve gives rather a remarkable relation between diameter and years of growth. If we let x = age of the tree and y = diameter in inches, we find that the equation $3\sqrt{x}=y$ is approximately the equation to the curve, and by using this equation we can arrive, approximately, at the age of trees grown in the forest.

The flattening of the curve at the 80th year is in accordance with the narrowness of the rings at these older years. In Fig. 3 is given the amount of wood produced in each decade. It will be noticed that the growth of the second decade is approximately twice that of the first decade. The maximum growth occurs in the fifth decade. To fully establish the year of maximum growth, more measurements will be necessary, though the year may vary according to local

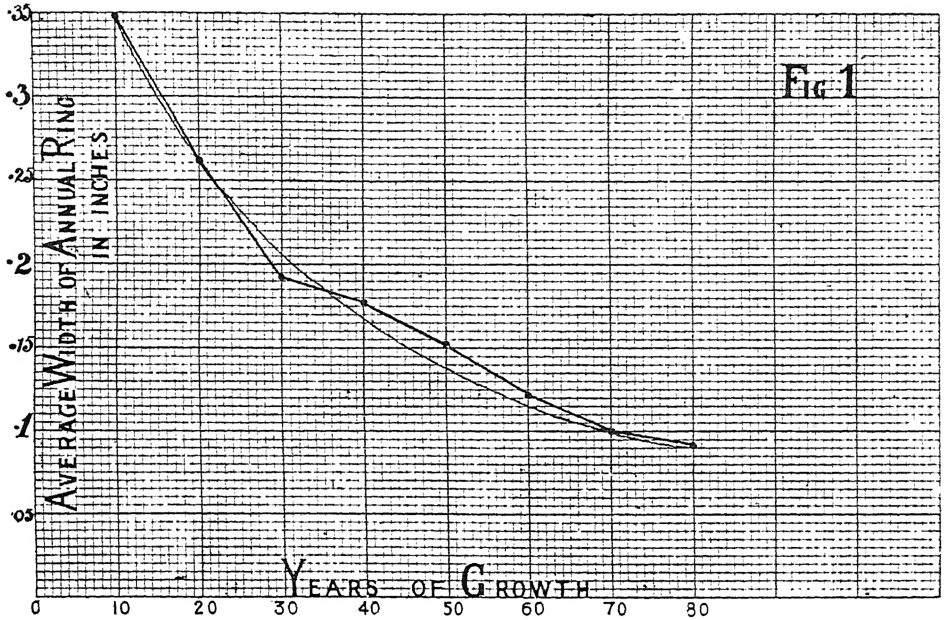
Fig 1
Average Width of Annual Ring in Inches
·35
·3
·25
·2
·15
·1
·05
Years of Growth
0
10
20
30
40
50
60
70
80

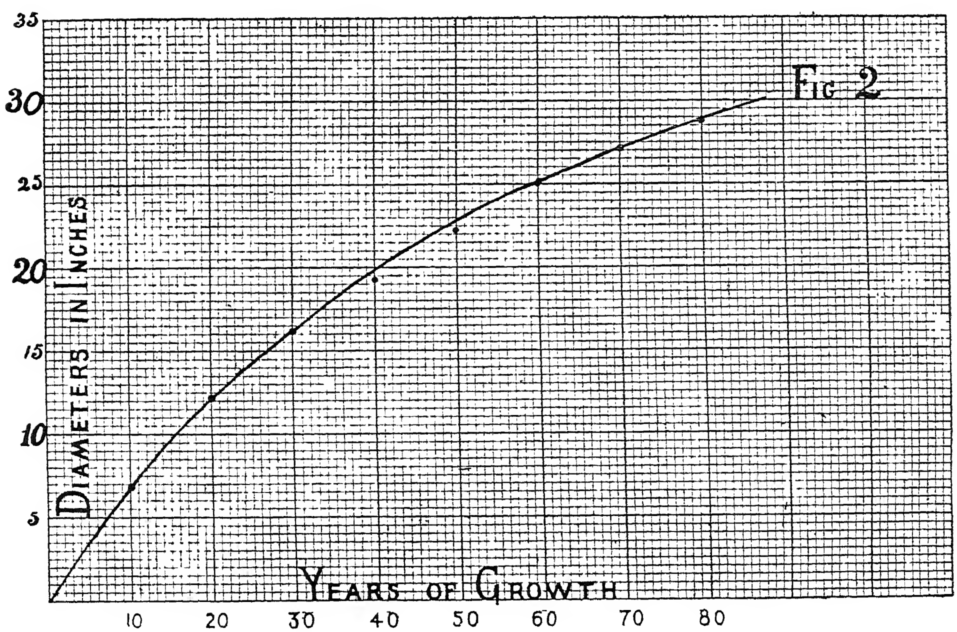
Fig 2
Diameters in Inches
35
30
25
20
15
10
5
Years of Growth
10
20
30
40
50
60
70
80

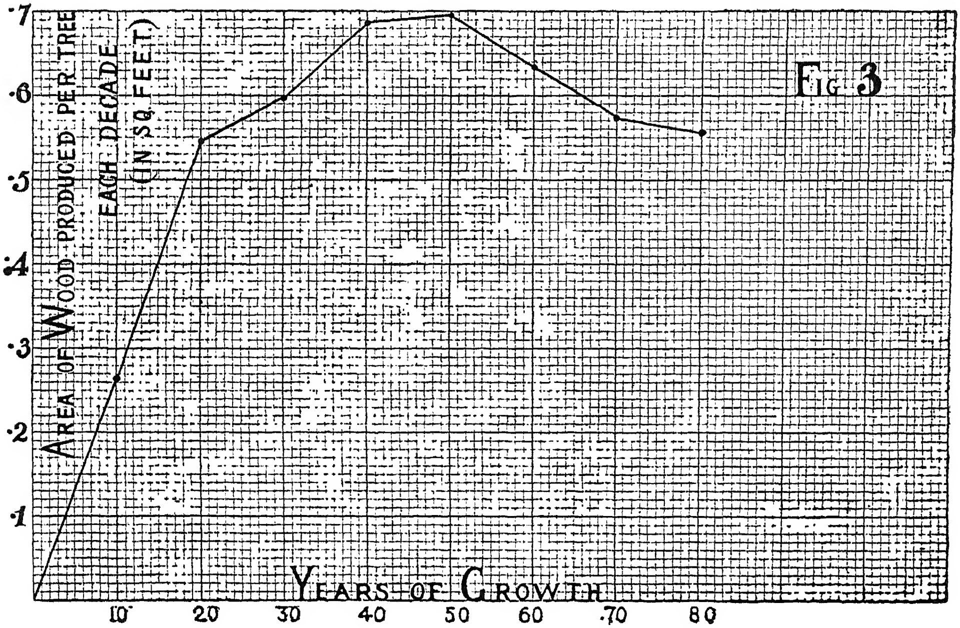
Fig 3
Area of Wood produced per tree each decade (in sq. feet)
·7
·6
·5
·4
·3
·2
·1
Years of Growth
10
20
30
40
50
60
70
80

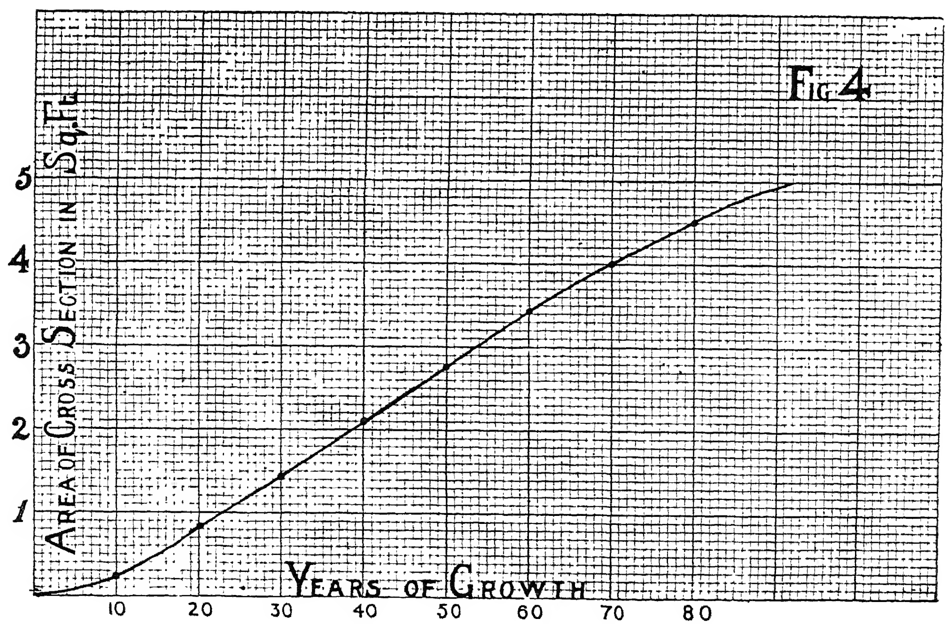
Fig 4
Area of Cross Section in Sq. Ft.
5
4
3
2
1
Years of Growth
10
20
30
40
50
60
70
80

conditions, thickness of planting, etc. It is evidently before the 50th year and after the 40th year. The curve rises somewhat sharply from the 30th to the 40th year, and falls from the 50th to the 60th, so that the maximum growth occurs between the 40th and 50th years. This is in accordance with the view that has been put forward from time to time. But although the tree reaches maturity, say, at its 50th year, it would not be correct to say that the tree is then fit for milling. The sap-wood is about 1 inch thick, and this represents so much waste. Further, the value of the wood produced in the next decade, that is, from the 50th to 60th year, may still give a good return on the money invested. But there is the further advantage in leaving the tree to grow on for a further period. Although the tree may have reached its maximum growth period, yet it cannot be deduced that the wood has reached its maturity; for it is quite probable that this wood will improve in quality during the next twenty years. From observations of the logs coming into the mill, it may safely be concluded that the tree at 80 years is still in health, and therefore there need be no fear of heart rot.

In Fig. 4 is given the total area of cross section during each decade. There is a gradual rise of the curve, indicating a gradual increase in diameter; but as in the other figs. we get a gradual flattening of the curve after we pass the 70th year. This flattening of the curve would indicate that the tree is losing its vitality, and is hence open to attacks of all kinds. This is borne out by a study of the standing forest, for there is a very intimate connection between the paucity of foliage on these old trees, and the small amount of wood produced in the older years.

From the study of the annual rings, then, we may conclude at present that the Mountain Ash reaches its maturity between the 40th and 50th years; but we are not entitled to conclude that the tree is then fit for milling. In view of the fact that in the future a large proportion of this timber will probably find its way on to the market in a dressed and seasoned condition, the tree cannot be said to be fit for milling until the wood is ripe. It may well be, that so long as the tree maintains a good head, the timber is improving in quality, and therefore it may be inadvisable to cut it during this period. There are other factors as well to be considered with regard to the time of harvesting the timber. The upkeep of this forest is small, at present, as compared with that of the forests of the old world. Hence interest charges will be much smaller, and we could therefore allow the forest to stand for a longer period than is the case with old world forests.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. I., 1917].

ART. II.—*On a Shell-bed underlying Volcanic Tuff near Warrnambool; with Notes on the Age of the Deposit.*

BY

FREDK. CHAPMAN, A.L.S.,

AND

CHAS. J. GABRIEL.

[Read 10th May, 1917].

1.—Occurrence of the Shell-bed.

Whilst on a visit to the Western District in 1912, the writers were informed by Mr. H. J. Hauschildt, of the Warrnambool Agricultural High School, of an interesting occurrence of a bed of shells in the dune-rock exposed at the mouth of the Hopkins River, on the right bank, close to the Boat-sheds. This occurrence seemed worth investigation from the fact that the shell-bed is completely covered by the tuffs of the Tower Hill series, an examination of the organic contents promising to throw some light on the age of the tuffs of the district and the building of the Tower Hill crater.

It is a matter of general knowledge amongst geologists that exposures of shell-beds are frequently found underlying the newer volcanic in this locality,[1] but so far as we are aware, no detailed examination of the fauna has been carried out. Hence, as a result of our visit these notes have been prepared, although owing to more pressing work they have been unavoidably delayed.

2.—Condition of the Shell-bed.

The stratum consists of a closely packed shelly and calcareous sandy deposit. The material is not consolidated by deposition from solution or by any secondary mineralisation, for it can be readily

1 Brough Smyth in his paper "On the Extinct Volcanoes of Victoria, Australia" (Quart. Journ. Geol. Soc. Lond., vol. xiv., 1858, p. 227), quotes a letter of A. R. C. Selwyn's dated August 11th, 1857, in which he says "Tower Hill is certainly the most recent volcanic vent I have yet seen. It appears, at least during its later eruptions, to have emitted vast quantities of ashes and scoriae; these are seen near Warrnambool, resting on beds of shell, sand and earthy limestone, containing numbers of living littoral species of mollusca."

broken up in the fingers and the sand is loose enough to be scraped out of the interior of the shells with the finger-nail.

The mollusca are in some cases polished, as though by wind action, and this also holds good for the foraminiferal shells. As a rule, however, the molluscan shells are dull and slightly weathered without being greatly worn. The finer siftings consist of abraded and polished sand-grains consisting of chips of the larger shells, echinoid fragments and foraminiferal tests, thus indicating a certain amount of aeolian action or sand-dune conditions.

3.—*Organic Contents.*

Order FORAMINIFERA.

Rotalia beccarii, Linné sp.

Nautilus beccarii, Linné, 1767, Syst. Nat., 12th ed., p. 1162; 1788, ibid, 13th (Gmelin's) ed., p. 3370, No. 4.

Rotalia beccarii, L. sp., Chapman, 1907, Journ. Quekett Micr. Club, ser. 2, vol. X., p. 139.

This widely distributed and even cosmopolitan form is represented here by a fairly large series. Its presence indicates a shallow-water or shore-line deposit with estuarine influence. As a fossil it is commonly found in Victoria in similar shallow water facies, from the Kalimnan (Lower Pliocene) upwards, but there is also one record of the species from the earlier series, the Janjukian, of Waurn Ponds, by Mr. Howchin. That authority has also recorded *R. beccarii* from the Kalimnan of Nor'-West Bend, Murray River; from the W. end of Torrens Lake, Adelaide; and from the upper beds of Muddy Creek. Howchin also found it in the Upper Pliocene of Dry Creek, South Australia, and in the Post-tertiary of Port Adelaide.[1] One of us has also noted *R. beccarii* in the Mallee bores from all three horizons, of Janjukian, Kalimnan and Werrikooian.[2]

The condition of the tests shows this species to have lived in a congenial habitat, the estuarine influence having been supplied by the Hopkins or equivalent stream, probably before its mature river bed had been disturbed by the local uplifts due to volcanic activity in the western district.

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1 See Rep. Austr. Assoc. Adv. Sci., Adelaide, 1893, pp. 351, 352.

2 Proc Roy. Soc Victoria, vol. xxvii (n.s.), pt. i, 1914, p 60.

Class PELECYPODA.

Fam. Leptonidae.

Genus **Erycina**, Lamarck.

Erycina helmsi, Hedley.

Erycina helmsi, Hedley, 1915. Proc. Linn. Soc. N. S. Wales, vol. XXXIX., pt. IV., p. 701, pl. LXXX., figs. 37-39.

This species was first described from the *Zostera*-beds at Deewhy Lagoon, N. S. Wales. In Victoria it has occurred at Port Melbourne, Corio Bay, Altona Bay, Port Albert and Lakes Entrance. It is fairly abundant in the Warrnambool fossil deposit.

Owing to the apparently slight difference between the fossils and the figured type we have conferred with Mr. Hedley as to their specific agreement, and he has kindly examined them, together with living specimens from Lakes Entrance and his own type specimen, and notes a possible difference in the fossils in "that the long end is more pointed in the fossil and more rounded in the recent." We find, however, every degree of variation in this respect, within small limitations, and there seems hardly enough evidence to warrant even a varietal distinction. The finely contused or pitted surface is as well marked on the fossil specimens as on the recent.

Fam. Veneridae.

Genus **Marcia**, H. and A. Adams.

Mărcia nitida, Quoy and Gaimard sp.

Venus nitida, Quoy and Gaimard, 1835, Voyage Astrolabe, Zool., vol. III., p. 529, pl. LXXXIV., figs. 13, 15 (in the text figs. 13, 14 in error).

Chione fumigata, Sowerby sp., Pritchard and Gatliff, 1903, Proc. R. Soc. Vict., vol. XVI. (N.S.), pt. I., p. 123.

Chione nitida, Q. and G. sp., Hedley, 1904, Proc. Linn. Soc. N.S. Wales, vol. XXXIX., p. 194. Pritchard and Gatliff, 1906, Proc. R. Soc. Vict., vol. XVIII. (N.S.). pt. II., p. 67.

Marcia nitida, Q. and G. sp., Hedley, 1917, Proc. Linn. Soc. N.S. Wales, vol. XLI., p. 691, pl. XLVI., figs. 2, 3.

The generic name of this shell, more familiarly known as *Chione* or *Tapes fumigatus*, has lately been the subject of discussion by Messrs. Dall and Jukes-Browne, and their argument is strongly in

favour of separating this and similar forms with smooth shells and uncrenulated margins, under the generic term Marcia.[1]

Practically all the valves of this species found in the fossil bed are deeper than in the living form, although occasionally one may meet with similar shells of recent origin.

This species was fairly common.

Fam. TELLINIDAE.

Genus **Tellina,** Linne.

Tellina deltoidalis, Lamarck.

Tellina deltoidalis, Lamarck, 1818, Anim. sans Vert., vol. V., p. 532. Pritchard and Gatliff, 1903, Proc. R. Soc. Vict., vol. XVI. (N.S.), pt. I., p. 115. Suter, 1913, Manual of N. Zealand Mollusca, p. 948 (Atlas), pl. LIX., fig. 11.

Several fragments of this common shore-living species occurred in the present deposit.

Fam. PSAMMOBIIDAE.

Genus **Soletellina,** Blainville.

Soletellina biradiata, Wood sp.

Solen biradiata, Wood, 1815, General Conch, p. 135, pl. XXXIII., fig. 1.

Soletellina biradiata, Wood sp., Pritchard and Gatliff, 1903. Proc. R. Soc. Vict., vol. XVI. (N.S.), pt. I., p. 114. Suter, 1913, Manual of N. Zealand Mollusca, p. 1083 (Atlas), pl. LXII., fig. 13.

Numerous specimens of the above species, mostly fragmentary, occur here.

Fam. MACTRIDAE.

Genus **Spisula,** Gray.

Spisula trigonella, Lamarck sp.

Mactra trigonella, Lamarck, 1818, Anim. sans Vert., vol. V., p. 479.

Gnathodon parvum, Petit, 1853, Journ. de Conch., vol. IV., p. 358, pl. XIII., figs. 9, 10.

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1 Dall. Proc. U. S. Nat. Mus., vol. xxvi., 1903, p. 335.
Jukes-Browne. Proc. Malac. Soc. Lond. vol. viii., 1909, p. 233 vol. x, 1914, p. 75.

Spisula parva, Petit sp., Pritchard and Gatliff, 1903, Proc. R. Soc. Vict., vol. XVI. (N.S.), pt. I., p. 108.

Mactra trigonella, Lam. Lamy, 1914, Bull. Mus. Nat. Hist., p. 205.

Spisula parva, Petit sp., Chapman, 1916, Rec. Geol. Surv. Vict., vol. III., pt. 4, p. 402.

Spisula trigonella, Lam. sp., Hedley, 1917, Proc. Linn. Soc. N.S. Wales, vol. XLI., p. 692.

Mr. Chas. Hedley has drawn attention to Dr. Lamy's identification of Lamarck's specimens of "*Mactra trigonella*" in the Paris Museum with our well-known *Spisula parva*, Petit sp.

Typical examples of this shell are here moderately common. It is well distributed round the coast, especially on muddy and sandy flats near the mouths of tidal rivers. In the Sorrento bore this species was found at a depth of 489 feet, associated with *Nassa labecula* and *Rotalia beccarii*.

Class GASTEROPODA.

Fam. Cyclostrematidae.

Genus **Pseudoliotia**, Tate.

Pseudoliotia micans, A. Adams sp.

Cyclostrema micans, A. Adams, 1850, Proc. Zool. Soc. Lond., p. 43. Dennant and Kitson, 1903, Rec. Geol. Surv. Vict., vol. I., pt. 2, p. 145.

Pseudoliotia micans, A. Adams sp., Pritchard and Gatliff, 1902, Proc. R. Soc. Vict., vol. XIV. (N.S.), pt. II., p. 102.

One small, but typical specimen found.

Fam. Littorinidae.

Genus **Diala**, A. Adams.

Diala lauta, A. Adams.

Diala lauta, A. Adams, 1862, Ann. Mag. Nat. Hist., ser. 3, vol. X., p. 298, No. 5. Pritchard and Gatliff, 1902, Proc. R. Soc. Vict., vol. XIV. (N.S.), pt. II., p. 88.

One specimen found.

Genus **Tatea**, T. Woods.

Tatea rufilabris, A. Adams sp.

Diala rufilabris, A. Adams, 1862, Ann. Mag. Nat. Hist., ser. 3, vol. X., p. 298.

Tatea rufilabris, A. Adams sp., E. A. Smith, 1882, Journ. Linn. Soc. Lond. Zool., vol. XVI., p. 268, pl. VII., fig. 19. Gatliff, 1905, Victorian Naturalist, vol. XXII., p. 15.

Three typical specimens of this interesting estuarine shell were found.

Genus **Bythinella**, Moquin-Tandon.

Bythinella nigra, Quoy and Gaimard sp.

Paludina nigra, Quoy and Gaimard, 1834, Voyage Astrolabe, Zool., vol. III., p. 174, pl. LVIII., figs. 9-12.

There appears to be a large and confusing synonymy for this very variable species, and the present writers have under examination evidence which seems to point to the above specific name as the valid one. Some of the confusion has arisen through bad drawing or inconsistent description, and it is hoped that a comparison of the various types involved will finally settle the question. At present the writers are in communication with some European authorities on the subject, the results of which will be made known as soon as possible. Examples of the so-called species, *victoriae*, *legrandi* and *petterdi* are found in this fossil deposit. The varieties occurring in the Pleistocene of Mowbray Swamp, Tasmania,[1] appear to most nearly approach *Bythinella victoriae*, T. Woods, the types of which are in the National Museum, Melbourne.

Fam. CERITHIIDAE.

Genus **Potamides**, Brongniart.

Potamides australis, Quoy and Gaimard sp.

Cerithium australe, Quoy and Gaimard, 1834, Voyage Astrolabe, Zool., vol. III., p. 131, pl. LV., fig. 7.

Potamides australis, Quoy and Gaimard sp., Pritchard and Gatliff, 1900, Proc. R. Soc. Vict., vol. XIII. (N.S.), pt. I., p. 156.

A solitary example of this estuarine shell was found.

Fam. BUCCINIDAE.

Genus **Nassa**, Lamarck.

Nassa pauperata, Lamarck sp.

Buccinum pauperata, Lamarck, 1822, Anim. sans Vert., vol. VII., p. 278, No. 56.

1 Chapman. Mem. Nat. Mus. Melbourne, No. 5, 1914, p. 57.

Nassa pauperata, Lam. sp., Pritchard and Gatliff, 1898, Proc. R. Soc. Vict., vol. X. (N.S.), pt. II., p. 279. Dennant and Kitson, 1903, Rec. Geol. Surv. Vict., vol. I., pt. 2, p. 143.

Rather rare.

Nassa labecula, A. Adams.

Nassa labecula, A. Adams, 1851, Proc. Zool. Soc. Lond., p. 98. Pritchard and Gatliff, 1903, Proc. R. Soc. Vict., vol. X. (N.S.), pt. II., p. 279.

This is a fairly common shell in the present deposit. It is generally a component of Victorian estuarine faunas of modern date.

Fam. AMPHIBOLIDAE.

Genus **Salinator**, Hedley.

Salinator fragilis, Lamarck sp.

Ampullaria fragilis, Lamarck, 1822, Anim. sans Vert., vol. VI., pt. II., p. 179.

Salinator fragilis, Lam. sp., Hedley, 1900, Proc. Linn. Soc. N.S. Wales, vol. XXV., p. 511. Gatliff, 1905, Victorian Naturalist, vol. XXII., p. 15.

A single specimen of this estuarine shell was found in the present deposit.

Class CRUSTACEA.

Fam. CYTHERIDAE.

Genus **Cythera**, Müller.

Cythere crispata, G. S. Brady.

Cythere crispata, G. S. Brady, 1868, Ann. Mag. Nat. Hist., ser. 4, vol. II., p. 221, pl. XIV., figs 14, 15. Idem, 1880, Rep. Chall., Zool., vol. I., pt. III., Ostracoda, p. 72, pl. XIV., figs. 8*a-d*. Chapman, 1914, Proc. R. Soc. Vict., vol. XXVII. (N.S.), pt. I., p. 33, pl. VI., fig. 9.

The present specimen is a short, broad variety, but possesses sufficient characters to enable us to refer it without hesitation to the above species. In the living condition it occurs on the shores of Great Britain, Norway and the Mediterranean; also at Port Jackson, Booby Island and in Hong Kong Harbour. In all these localities it is a moderately shallow water form. One of us (F.C.)

has lately recorded it from "Endeavour" material from South Australia at 100 fathoms. In the fossil condition it occurs in the northern hemisphere in the Pleistocene of Scotland, Ireland and Norway; whilst in Victoria it has been obtained in much older beds, viz., the Miocene or Janjukian of the Mallee bores.

Fam. BALANIDAE.

Genus **Balanus**, Lister.

Balanus sp.

A rostral compartment of a species of *Balanus*, having an obscure rugo-costulate ornament occurs here. It has some resemblance to *Balanus psittacea*, Molina sp., but is not so heavy in structure.

4.—Fossil Mollusca from Dennington, near Warrnambool.

These shells occurred at a depth of 8 feet from the surface and underneath volcanic tuff, at Nestles Milk Factory. This locality is about 1½ miles inland from the present coast-line.

Arca (Anadara) trapezia, Deshayes
Marcia nitida, Q. and G. sp.
Tellina deltoidalis, Lam.
Soletellina donacioides, Reeve
Donax deltoides, Lam.
Mactra polita, Chemnitz
Spisula trigonella, Lam. sp.
Mesodesma elongata, Deshayes
Patella ustulata, Reeve
Turbo undulatus, Martyn sp. (operculum)
Bankivia fasciata, Menke sp.
Potamides australis, Q. and G. sp.
Cymatium spengleri, Chemn. sp.
Nassa jacksoniana, Q. and G. sp.
Nassa labecula, Adams

The above collection was presented to the National Museum by Mr. D. J. Mahony, M.Sc., April 24th, 1912.

From the same locality Mr. H. J. Hauschildt, on Oct. 5th, 1912, presented, amongst other specimens, the following additional species:—*Pecten bifrons*, Lam.; *Mytilus hirsutus*, Lam.; *Venus (Chione) strigosa*, Lam.; and *Purpora succincta*, Martyn sp.

5.—*Holocene Mollusca from Lake Pertobe.*

This deposit probably belongs to a later episode than the shell-beds underlying tuffs. The locality is S. of Warrnambool and quite close to the coast-line.

Venerupis crenata, Lam. sp.
Tellina deltoidalis, Lam.
Spisula trigonella, Lam. sp.
Soletellina biradiata, Wood sp.
Soletellina donacioides, Reeve
Monodonta (Austrocochlea) constricta, Lam. sp.
Risella melanostoma, Gmelin sp.
Potamides australis, Q. and G. sp.
Bittium cerithium, Q. and G. sp.
Nassa labecula, Adams.
Salinator fragilis, Lam. sp.

These specimens were found by Mr. H. J. Hauschildt and donated to the National Museum, March 18th, 1908.

6.—*General Remarks on the Age of the Old Dune-rock and associated shell-beds.*

The dune-rock of Warrnambool, like that of Sorrento, owes its origin mainly to the remains of shells, and is therefore almost entirely calcareous. That both of these rocks are far from modern, historically speaking, is proved by the occurrence in the Sorrento dune-rock of the remains of an extinct kangaroo, *Palorchestes*, represented by pelvis, scapula, portions of ribs and a tooth, as recorded by Prof. J. W. Gregory;[1] whilst that at Warrnambool has yielded the footprints of a gigantic bird, probably *Genyornis*, a contemporary of *Diprotodon* in South Australia.

The Warrnambool dune-rock affords an added interest to geologists, in its relationship to what are probably the latest effusions of volcanic ejectamenta in Victoria, for as we have seen, shell-beds, consisting practically of existing species occur in this locality overlain by volcanic tuffs[2] similar to those of Tower Hill.

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1 Proc. Roy. Soc. Victoria, vol. xiv. (n.s.), pt. i., 1901, pp. 139-144. Gregory concludes his paper with these remarks:—"Accordingly the lower exposed part of the Sorrento dunes dates back to the time of extinct kangaroos, the age of which is described as late Pliocene or Lower Pleistocene."

2 Volcanic tuff as defined by Prof. Judd and quoted by Prof. J. W. Gregory is stated to consist of "the finely divided materials, which, owing to the storms of rain which frequently accompany volcanic eruptions," descend in the condition of mud, which flows evenly over the surface of the growing cone and consolidates in beds of very regularly stratified tufa or tuff.

In regard to the plant remains of the tuff-beds, it is worth recording that a block of tuff containing what are probably *Eucalyptus* leaves, was obtained by Mr. Hauschildt[1] some years ago, when the foundations for the Milk Factory at Dennington were being excavated. Data of age derived from fossil floras of so recent a stage are not, however, of much value, seeing that their types are more persistent than those of animals. Thus the tuffs of Mount Gambier have yielded fronds of the Bracken fern (*Pteris aquilina*) and of *Banksia*, practically identical with plants now living in the same locality.

The Hampden tuffs of the Camperdown district[2] are in all probability of the same age as those of Warrnambool and have covered ancient swamps such as those of the Pejark Marsh. In samples of this ancient mud deposit which were submitted to one of us (F.C.) by Mr. R. H. Walcott, Curator of the Technological Museum, there were found diatomaceous frustules and remains of a species of *Cyperus* indistinguishable from the living *Cyperus lucidus*.

The extinct marsupial bones found on the shores of the crater lakes of the Camperdown district are probably contemporaneous with the tuff beds, as note the opinion of Prof. Sir Baldwin Spencer and Mr. R. H. Walcott regarding those from Lake Colongulac[3] :—

"No bones have been found in situ as far as we are aware, those found having been picked up on the shores of the lake, but there is no doubt, like those of the Pejark Marsh, that they were originally deposited in a swamp or lagoon which was afterwards buried under the ashes ejected by the neighbouring volcanoes; the bones in this instance being subsequently freed by the breaking up of the old bed and cast upon the shores of the lake."

SUMMARY.

From the foregoing discussion it may be assumed that :—

1.—The shell-bearing beds underlying the volcanic tuffs near Warrnambool belong to the same episode as the older dune-rock accumulations of that locality and Sorrento, and the swamp deposits under the tuffs of the Camperdown district.

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1 This specimen, presented by Mr. Hauschildt, is now in the National Museum and can be seen in the wall-case of the Australian Gallery.

2 Mem. Geol. Surv. Vict., No. 9, 1810. "Geology of the Camperdown and Mount Elephant District." Grayson and Mahony, p. 6.

3 Proc. Roy. Soc. Victoria, vol. xxiv. (n.s.), pt. i., 1911, p. 114.

2.—That since the old dune-rock and old swamp deposits contain extinct forms of marsupial remains they presumably belong to the early Pleistocene.

3.—The evidence of the shells from beneath the Warrnambool tuffs shows the fauna to have a geologically recent aspect, but with varietal modifications of the species indicating different geographical features from that now prevailing in the locality, a strong estuarine character antedating the re-juvenation of the present river-system. This ancient estuarine feature is further emphasised by the fact of the prevalence of a wide lava-flow of newer basalt extending down to the present shore-line at Port Fairy and beyond, pointing to the infilling of an ancient river delta which, originally of great extent, embraced the Warrnambool-Portland area.

4.—It may therefore be postulated that the volcanic tuffs of the Tower Hill series were ejected between early Pleistocene and fairly modern times, that is, in late Pleistocene or Holocene, or, using European terms, in early prehistoric times. Compared with the more mature physiographic features shown by the newer volcanic lava flows, these tuffs represent one of the last stages of the volcanic outburst in Victoria.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. I., 1917].

ART. III.—*The Cause of Bitter Pit.*

BY ALFRED J. EWART, D.Sc., PH.D.

(Professor of Botany and Plant Physiology in the Melbourne University, and Government Botanist of Victoria).

[Read 10th May, 1917].

In his fourth report upon this "disease," Mr. McAlpine in summing up refers the origin of Bitter Pit to two causes, both connected with the supply of water.

The first cause is considered to be due to irregularities of growth, the pulp growing more rapidly than the network of vessels, "so that meshes here and there are not formed and the loss of water at these spots cannot be fully met by a fresh inflow of sap. This causes the cells to collapse, the sap reaches an injurious concentration, causing the cells to die and turn brown."

The second cause is supposed to be the exact opposite of this, namely that an excess of water causes so great an increase in the pressure within the cells that they rupture and die, producing the characteristic appearance of Bitter Pit.

In regard to the first cause, since it is a morphological change readily capable of demonstration, one would expect to find some evidence of its existence brought forward. No such evidence is given in the whole of the voluminous reports. The statement is a supposition of possibility not based upon actual observation, and immediately contradicted by observed facts. Bitter Pit spots occur both on and near vascular bundles with healthy cells existing in the tissue further out supplied by the same bundles. Any interruption of the vascular supply would naturally affect all the tissue supplied by the bundles. In some cases a layer of bitter pit tissue may spread over a square centimetre or more extent, and crossing the course of a whole series of bundles. Nevertheless healthy tissue supplied by the same bundles may exist beyond the affected area, showing that the death of the affected cells cannot be due to an interruption of the vascular supply.

In regard to the second cause, excess of water causing an increased pressure bursting the pulp cells, it may be noted that the pressure within the pulp cells depends upon the osmotic concentration of the cell-sap within them, and that an abundant supply of water simply enables the full osmotic pressure to be exerted. In a

tissue, an increase of osmotic pressure simply causes the cells to press more firmly against one another and the tissue expands as a whole, sometimes leading in the case of thin-skinned apples floated on water to the bursting of the outer skin, but not to a bursting of the pulp cells. A bursting of the outer skin does not accompany the development of Bitter Pit, which on this theory it should do.

In addition apple pulp may be immersed in water without the cells being at first injured or bursting. Later they may die and brown, and in soft fleshed apples the pulp cells may separate singly or in clusters, but again without bursting, although here the supply of water is greater than ever exists when the fruit is on the tree. Both the bursting and the vascular interruption theories fail entirely to take account of the actual sequence of events in the development of Bitter Pit. In the early proteid stage of the apple, no signs of the disease are shown. During the starch stage, in certain localized areas the starch grains remain undissolved in groups of cells, which are at first colourless and living. These cells later die, turn brown and may collapse or shrivel. The first symptom of the disease is the non-solution of the starch grains. Now to prevent a dry starch grain from absorbing water a pressure of 2500 atmospheres is necessary, so that a pressure at least approaching this would be necessary to prevent it dissolving under the action of an enzyme, such as diastase, which can only act in the presence of water. The maximum pressure of the ascending sap is less than 1 atmosphere and the maximum osmotic pressure in apple cells containing 10-15 per cent. of sugar is 12 to 20 atmospheres. It is well known that in cells with quite as high osmotic pressures as this starch grains dissolve readily, and actual tests have shown that bitter pit tissue is more deficient in sugar than the ordinary pulp, which is the direct result of the non-solution of the starch grains. To invoke changes of sap pressure or of osmotic pressure as a cause of bitter pit is therefore a transparent absurdity.

Mr. McAlpine (p. 73) states "the theory of spraying with poisonous compounds was brought forward as a direct and definite cause. That theory has now been abandoned and the absorption of poison from the soil in infinitesimal quantities through the roots substituted for it." In justice to Dr. White who first put forward the poisoning theory of Bitter Pit, so misleading a statement cannot be allowed to pass uncontradicted. In the paper in question[1] Dr. White sums up in the following words: "The results of my

1 Proc. Roy. Soc. Victoria, 1911, p. 16.

observations seem to indicate that the complaint known as bitter pit is, strictly speaking, not a disease at all, but rather a symptom of slow local poisoning, and that in the cases actually examined so far it appears to be due to the poisonous compounds sprayed on to the surface of the fruits."

"Though as far as my observation and experiments go, I have limited them to the supposition that the spray passes through the breathing pores of the fruit, from the exterior, it is by no means impossible that some of the spray which falls on the ground or is washed down by the rain, and gradually accumulates in the soil, might enter the plant through the root hairs. That soil is capable of retaining arsenical compounds for a considerable length of time is well known, and when an orchard is sprayed 6 to 16 times in one season[2] the amount of poisonous spray reaching the soil must become quite appreciable. The sensitive fruit cells would probably be more susceptible to poison than the other parts of the plant, since the living protoplasm is reduced to a mere attenuated film, but this would necessarily be a matter for future investigation."

The statement that Dr. White's original theory has been abandoned and another substituted for it is therefore highly misleading. The essential point is that the complaint known as bitter pit is not a disease but a symptom of slow local poisoning, and evidence in support of this is steadily accumulating. The nature and origin of the poisons in question is a subsidiary matter. Dr. White informs me that as the result of several years' work on testing the influence of poisons on Prickly Cactus and other plants, she has come to the conclusion that bitter bit symptoms are not confined to such fruits as the apple and pear, but may also occur in leaves and stems, and as in the apple and pear may not only occur naturally but may be produced artificially by the direct application of poisons. It is indeed possible that certain obscure plant tumours and malformations may be the direct or indirect result of oligodynamic poisoning.

Potatoes grown in newly cleared acid soils often develop brown spongy patches of dead tissue internally which are not accompanied by any disease organisms. This and the disease known as "brown fleck" may be further instances of natural oligodynamic poisoning. The dead cells here also contain undissolved starch grains in quantity, whereas in dead patches produced by parasitic

2 Largely as the result of Dr. White's work spraying is no longer carried to the absurd extremest hat were formerly common, and it is more generally recognised that the smaller the amount of poisonous material used to produce the result required, the better it is for the plant and for the soil.

organisms, the starch grains are dissolved away. If metallic poisons are responsible for these defects, their presence should be capable of demonstration by direct analysis, since potatoes are much less sensitive to metallic poisons than are apples. Organic poisons are, however, also a possible cause, for it is now well known that the infertility to crops of certain peaty and other soils is due to the presence of traces of organic poisons of the nature of phenols, or creosote-like combinations.

The late Dr. Rothera carried out some experiments in the direction of endeavouring to produce bitter pit symptoms by the direct absorption of dilute solutions of metallic poisons. Cut leafy branches bearing fruit were placed in solutions of copper sulphate and mercuric chloride of strengths varying from 1 in 100,000 to 1 in 600,000. The results obtained were negative. The tests, however, only lasted a fortnight, and were discontinued on account of the shrivelling of the apples. The latter is due to the rapid blocking of the cut surface preventing the absorption of water (and poison). If the experiment is carried out differently by driving in the poisonous solution under a head of 5 or 6 feet of water or roughly one-sixth of an atmosphere positive results are easily obtained in a few days, and although the browning usually takes place along the veins, it is often strikingly reminiscent of bitter pit. When these tests were performed in the unripe starch stage, the apple always died before all the starch grains had dissolved in the unpoisoned pulp cells, but I have already shown that if dilute poisons are injected into young apples while on the tree, although most of the treated apples usually fall, some remain and ripen on the tree. These show bitter pit areas at the points injected and these areas show every sign of normal bitter pit, including the presence of starch grains in brown cells, while the surrounding healthy tissue contains no starch.

A second test carried out by Rothera was by watering apple trees with solutions of copper sulphate of 1 in 100,000 strength.

The following results were obtained :—

	Yield.	Pitted.	% Pitted.
Counted by Mr. McAlpine—			
Gravenstein	100	8	8
Jonathan	164	16	9.7
Counted by Dr. Rothera—			
Charles Ross	48	10	20.8

Mr. McAlpine, however, states that the trees used were previously liable to Bitter Pit. Why such trees were selected for the test is difficult to say. To be conclusive the tests would need to be repeated

on a larger scale over at least 2 years, and on trees whose previous history was known.

The present position in regard to the theories of the origin of bitter pit may therefore be summed up as follows :—

(1) The bursting cell theory is founded on a confusion between cause and effect. The cracks in the cell walls sometimes seen in sections of dead bitter pit tissue are either cracks caused after death by drying and contraction, or more usually are tears produced by the razor. In sections cut from tissue imbedded in paraffin the cracks are rarely seen, and are often entirely absent.

(2) The vascular interruption theory is unsupported by any morphological evidence, and is contradicted by direct evidence such as the existence of healthy tissue beyond bitter pit areas where according to the theory vascular interruption should have occurred. Further, the occurrence of starch in the cells shows that the channels along which carbohydrates are conveyed to the bitter pit tissue must have been open and functioning freely.

(3) The poisoning theory has behind it the weight of the following evidence :—

Every symptom of this defect can be produced by the artificial application of poisons, including the presence of starch grains in dead cells.

Various observers have noted similar results in leaves and young stems as the result of the application of poisonous sprays (patches of dead tissue with brown shrivelled cells packed with starch.) In apples the sensitivity is so great that the poisoning may be oligodynamic, i.e., poisoning may occur in the presence of traces of poison beyond detection by ordinary chemical analysis.

As apples ripen the sensitivity of the pulp cells to poison increases, so that an apparently sound apple may develop bitter pit after it has been picked.

There is a close correspondence between resistance to poison and resistance to bitter pit. The most resistant variety to bitter pit (Yates) is also the most resistant to poison. Varieties specially sensitive to poison are also specially sensitive to bitter pit. There is also a close correspondence in regard to temperature effects. At low temperatures the development of bitter pit is checked or retarded. Similarly at low temperatures the resistance to poisons is greatly increased, being 10 to 100 times greater at 0°C what it is at 25°C.

Further, there is evidence to show that where a comparison is possible the incidence of bitter pit is greater in orchards that have

been heavily sprayed for some time than in orchards which have been lightly sprayed or not sprayed at all. It is unfortunate that statistics on this point, which by now should have been available in abundance have not been published. It is quite beside the point to indicate the existence of bitter pit in unsprayed orchards as a complete and satisfactory answer. If bitter pit is simply the result of local oligodynamic poisoning, any trace of any poison capable of absorption may produce it, independently of how it is absorbed and whether it is originally present in the soil or not.

The Browning of Bitter Pit Tissue.—In certain varieties of apples, notably Statesman, the pit tissue is usually paler than in other varieties. The browning is due to the action of the oxidase liberated from the dying protoplasm upon the tannic acid of the cell sap. When a Statesman apple is cut, the cut surface remains paler than in most apples, the browning being most evident along the veins. This might be due either to a deficiency of oxidase or of tannin or to the presence of an oxidase inhibiter. More than one distinct variety of apple has been known as Statesman. One of these false Statesmans is known as Chandler's Seedling. Its pulp browns readily when cut. The sap was expressed from equally ripe true Statesman and from Chandler's Seedling and tested for tannic acid; the former yielded 0.24 and the latter 0.16, a difference which is hardly sufficient to explain the pronounced difference of browning.

Testing with guiacum and peroxide of hydrogen for oxidase gave about the same depth of blue, but this test though a delicate one does not discriminate quantitively. A dilute solution of amidol is a good test for apple oxidase. By adding varying quantities of apple sap until the rate of change of colour was the same in each case, it was found that three parts of Chandler sap contained as much oxidase as 8 parts of Statesman sap. The glycerine extract from pulp dried by pressure gave values of 3 and 9 respectively. No evidence of the presence of any special inhibiting agent could be obtained, so that the feeble browning of Statesman pulp is mainly due to a deficiency of oxidase. The amount of oxidase present in an apple can therefore to some extent be used as a test to distinguish between certain varieties.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. I., 1917].

ART. IV.—*Additions to and Alterations in the Catalogue of the Marine Shells of Victoria.*

BY

J. H. GATLIFF

AND

C. J. GABRIEL.

(With Plate III.).

[Read 12th July, 1917].

In this paper we have added four more species to, and deleted six from the catalogue, and revised the generic and specific names of others.

MUREX FIMBRIATUS, Lamarck.

1822. Murex fimbriatus, Lamarck. Anim. s. vert. vol. vii., p. 176.

1845. Murex planiliratus, Reeve. Conch. Icon, vol. iii., pl. 31, f. 149.

1898. Murex planiliratus. Reeve. Pritchard and Gatliff, P.R.S. Vic., vol. x. (New Series), p. 254.

1902. Murex planiliratus, Reeve. Hedley, P.L.S., N.S.W., vol. xxvi., p. 700.

1916. Craspedotriton fimbriatus, Lamarck. Hedley, Jour. Royal Soc. Western Australia, vol. i., for 1915, p. 64.

Hab.—West Head, Western Port; Portland.

Obs.—Reeve's remarks about Ricinula fiscellum, Broderip, are rather lengthy; he gives a very good figure of that species; it differs entirely from his figure of M.planitiratus. He concludes by stating: "It only remains to enquire of M. Kiener whether the shell mistaken for it (M.fiscellum), and which received so many names in different States, is not the Murex fimbriatus Lam." Mr. Hedley has cleared up this difficulty by examining Lamarck's specimens in the

Geneva Museum of M.fimbriatus; but we do not think Dall's definition of Craspedotriton permits of the inclusion of this species. We have a specimen before us of Triton convolutus, Broderip, the type of Dall's genus Craspedotriton, and also his description of the genus.

In his description of M.fimbriatus, Lamarck says: "Apertura roseo-violacesente," this indicates its inclusion as a Coralliophila. None of our specimens of M. planiliratus from this coast or from Western Australia have any coloration within the mouth.

Genus **Kalydon,** Hutton 1884.

KALYDON VINOSUS, Lamarck.

1822. Buccinum vinosum, Lamarck. Anim. s. vert. vol. vii., p. 275.

1898. Sistrum adelaidensis, Crosse and Fischer. Pritchard and Gatliff. P.R.S. Vic., vol. x. (New Series), p. 259.

1913. Kalydon vinosus, Lamarck. Hedley, P.L.S. N.S.W. vol. xxxviii., p. 330.

Hab.—Coast generally. A common littoral species.

Obs.—Lamarck's type has never been figured, and its identity was unknown here until Mr Hedley examined it in the Geneva Museum. He says: "Three specimens apparently cotypes of Buccinum vinosum."

We agree with Mr. Hedley that it has been misplaced in the genus Sistrum.

In form and sculpture this species varies greatly. It attains to a length of 22 mm., and the adult form usually developes four or five strong denticles within the outer lip.

DIALA PULCHRA, A. Adams.

1862. Alaba pulchra, A. Adams. A.M.N.H., vol. x., 3rd ser., p. 296, No. 15.

1902. Diala pulchra, A. Adams. Pritchard and Gatliff. P.R.S., Vic., vol. xiv.; p. 89.

1913. Diala pulchra, A. Adams. Hedley, P.L.S. N.S.W., vol. xxxviii., p. 286, pl. 18, fig. 57.

1915. Diala pulchra, A. Adams, May, P.R.S. Tas., p. 77.

Hab.—Port Phillip; Western Port.

Obs.—A rather common species. Figured for the first time by Mr. Hedley, as above quoted.

DIALA VARIA, A. Adams.

1861. Diala varia, A. Adams. A.M.N.H. vol. viii., 3rd ser., p. 243.

1902. Diala varia, A. Adams. Pritchard and Gatliff. P.R.S. Vic., vol. xiv., p. 89.

1913. Diala varia, A. Adams. Hedley, P.L.S. N.S.W., vol. xxxviii., p. 286, pl. 18, fig. 56.

Hab.—Western Port; Puebla Coast.

Obs.—Figured for the first time by Mr. Hedley, as above quoted.

TORNATINA FUSIFORMIS, A. Adams.

1854. Bulla (Tornatina fusiformis, A. Adams. Thes. Conch., vol. ii., p. 570, pl. 121, f. 37.

1859. Tornatina apicina, Gould. Proc. Bost. Soc. Nat. Hist. vol. vii., p. 139.

1862. Tornatina apicina, Gould. Otia Conch. p. 112.

1878. Tornatina apicina, Gould. T. Woods, P.L.S. N.S.W. vol. ii., p. 256.

1883. Utriculus avenarius, Watson. J.L.S. Lon., vol. xvii., p. 328.

1886. Utriculus avenarius, Watson. Chall, vol. xv., p. 658, pl. 49, f. 5.

1893. Tornatina apicina, Gould. Pilsbry, Tryon Man. Conch. vol. xv., p. 201.

1893. Tornatina avenaria, Watson. Pilsbry, *Id.* p 202, pl. 24, f. 37 and 38.

1903. Tornatina fusiformis, A. Adams. Pritchard and Gatliff, P.R.S. Vic. vol. xv. for 1902, p. 212.

1903. Tornatina brenchleyi, Angas. Pritchard and Gatliff. *Id.* p. 212.

1912. Tornatina fusiformis. A. Adams. Verco, T.R S.S.A., vol. xxxvi., p. 204.

1913. Retusa apicina, Gould. Hedley, P.L.S., N.S.W., vol. xxxviii., p. 337.

1916. Retusa apicina, Gould. Hedley, Jour. Royal Soc. Western Australia, vol. i., for 1915, p. 72.

Hab.—Sandringham, Sorrento, Portsea, Port Phillip; Balnarring, Shoreham, Flinders, San Remo, Western Port; Kilcunda; Portland.

Obs.—We are of opinion, after examining numerous examples of this species, from this coast, New South Wales, and Tasmania, that

although they differ in size, length of spire, and outline of the lip—which is occasionally more patulous—that there is only one species, as indicated above, and that the specimens that we have examined exhibit the slight variation comprised in the description and figures of the forms included in the above synonymy.

We also have examples of the species from Durban, South Africa, and from the same locality, *T. hofmani*, Angas.

Pilsbry remarks on the genus,[1] "Tornatina differs from Retusa in the conspicuously channeled suture, and the peculiar projecting apex." These are distinguishing features in the type of the genus *T. voluta*, Quoy and Gaimard.

Iredale asserts[2] that the genus Tornatina is a synonym of Retusa. Before accepting this we should like to examine the apex of what is authentically regarded as being typical species of Retusa.

LEPIDOPLEURUS CANCELLATUS, Sowerby.

1908. Lepidopleurus cancellatus, Sowerby. Gatliff and Gabriel, P.R.S. Vic., vol. xxi. (New Series), p. 383.

Obs.—We withdraw the record of the occurrence of this species on our coast. Our shell so identified is the species named, Ischnochiton gabrieli, Hull.

LEPIDOPLEURUS COLUMNARIUS, Hedley and May.

1908. Lepidopleurus columnarius, Hedley and May, Rec. Aust. Mus. vol. vii., p. 123, pl. 24, f. 27, 28.

1912. Lepidopleurus pelagicus, Torr, T.R.S.S.A., vol. xxxvi., p. 165, pl. 5, f. 2a-f.

1913. Lepidopleurus columnarius, Hedley and May. Gatliff and Gabriel, P.R.S. Vic. vol. xxvi. (New Series), p. 78.

Hab.—Bass Straits, Commonwealth trawler "Endeavour."

Obs.—Dr. Torr has kindly permitted us to examine with him his type of L.pelagicus, and we find it conspecific.

ISCHNOCHITON WILSONI, Sykes.

1896. Ischnochiton wilsoni, Sykes. P. Malac. Soc. Lond. vol. ii., p. 89, pl. 6, f. 1, 1a.

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1 Tryon Man. Conch., vol. xv., p. 182.

2 P. Mal. Soc. Lond., vol. xi., 1915, p. 300.

1903. Ischnochiton wilsoni, Sykes. Pritchard and Gatliff, P.R.S. Vic., vol. xv. (New Series), for 1902, p. 202.

1912. Ischnochiton levis, Torr, T.R.S.S.A. vol. xxxvi. p. 168, pl. 6, f. 6 a-f.

Hab.—Port Phillip Heads (J. B. Wilson).

Obs.—Dr. Torr also gave us the type of his species to compare it with the type of I.wilsoni, which is in our National Museum. This we have done, and find it to be conspecific. He has requested us to record this fact. His specimen is three-quarters the length of the type of I.wilsoni, which has ten slits in the tail valve. Dr. Torr's has eight or nine in the tail valve. It has been preserved in a solution of formalin, and, consequently, lost most of its coloration, and is in a bad state of preservation. The figure of the head valve of I.wilsoni shows twelve slits regularly disposed. The description states that it has nine slits irregularly disposed.

Ischnochiton proteus, Reeve.

1847. Ischnochiton proteus, Reeve. Conch. Icon. vol. iv., pl. 18, f. 111.

1867. Lepidopleurus proteus, Reeve. Angas, P.Z.S., Lond., p. 222.

1892. Ischnochiton divergens, Pilsbry, (not of Reeve), Tryon's Man. Conch. vol. xiv., p. 91, pl. 22, f. 74-77.

1916. Ischnochiton proteus, Reeve. Iredale and May, P. Mal. Soc. Lond. vol. xii., pp. 109 and 110.

Hab.—Ocean beach, Point Nepean; Shoreham, and San Remo, Western Port.

Obs.—We have had specimens sent to us from New South Wales under the name of I.divergens, Reeve, but that species has minute girdle scales; in I.proteus they are large and solid; in both species the scales are transversely striated.

It is a handsome species, the predominating colour being green. Interior of tail plate has a central crescent of blackish-green, and in some specimens the interior of the median valves are stained in the centre with magenta colour.

Ischnochiton atkinsoni, Iredale and May.

1916. Ischnochiton atkinsoni, Iredale and May. P. Mal. Soc. Lond., vol. xii., p. 110, pl. 4, f. 3.

Hab.—Shoreham, Western Port.

Obs.—A small, pale buff coloured species.

Ischnochiton arbutum, Reeve.

1908. Ischnochiton arbutum, Reeve. Gatliff and Gabriel P.R.S., Vic. (New Series), vol. xxi., p. 384.

Obs.—Having received specimens of this species from Iredale, which were obtained at Cape York, Queensland, and that have been compared with the type, we find that our previous record has been made upon a wrongful identification, and therefore withdraw it as occurring on our shores.

Ischnochiton sculptus, Sowerby.

1908. Ischnochiton sculptus, Sowerby. Gatliff and Gabriel. P.R.S. Vic. (New Series), vol. xxi., p. 383.

Obs.—We also withdraw the record of this species occurring on our coast. Our shell so identified was subsequently named Ischnochiton falcatus, Hull.

Ischnochiton lineolatus, Blainville.

1825. Chiton lineolatus, Blainville, Dict. Sc. Nat. vol. xxxv., p. 541.

1893. Chiton lineolatus, Blainville. Pilsbry, Tryon's Man. Conch. vol. xv., p. 105.

1916. Ischnochiton lineolatus, Blainville. Iredale and May, P. Mal. Soc. Lon., vol. xii., p. 108, pl. 4, f. 1.

Hab.—Port Phillip Heads; Port Fairy; Western Port.

Obs.—At the reference last quoted above, it is stated that the identification of this species by Australian and Tasmanian writers as being I.contractus, Reeve, is incorrect. Iredale and May have now identified it as I.lineolatus.

Ischnochiton (Stenochiton) pallens, Ashby.

1900. Ischnochiton (Stenochiton), pallens, Ashby, T.R.S.S.A. vol. xxiv., p. 86, pl. 1, f. 1 a-e.

1912. Ischnochiton (Stenochiton) pallens, Ashby. Torr, *Id.* vol. xxxvi., p. 143.

Hab.—Port Phillip Heads.

Obs.—When examining at the National Museum the collection of Chitons obtained by Wilson, and dealt with by Sykes, we noted that he had wrongly identified one as I.juloides, Adams and Angas. We considered it to be what was subsequently named I.pallens, Ashby. The Curator kindly lent us the specimen to send to Mr. Ashby for his opinion. Mr. Ashby writes to us upon it: "While it may be

classed with *pallens*, you will note several differences. In yours the lateral areas are more raised, and the growth lines are strongly in evidence, which is not the case with *pallens*. The angle of the anterior valve in yours is not quite the same; yours shows a slight bulge towards the apex. While the anterior valve in yours is short, it is barely as proportionately short as in *pallens*, but it certainly has a short anterior valve so characteristic of *pallens*. The posterior valve does not show the mucro far back on a long valve, but that may be due to its damaged condition. Yours suggests a little more carination, but this may also be due to damage. In conclusion I should place your shell with *pallens*."

Mr. Ashby kindly sent us his only co-type for comparison. We quite agree with his remarks. Our specimen is not quite half the length of the co-type. We have not yet found I. juloides on our coast.

CARDIUM CYGNORUM, Deshayes.

1903. Cardium cygnorum, Deshayes. Pritchard and Gatliff, P.R.S. Vic., vol. xvi. (New Series), p. 135.

1916. Cardium cygnorum, Deshayes. Hedley, J.R.S.W. Aust., vol. 1, for 1915, p. 13.

1917. Cardium cygnorum, Deshayes. Hedley, P.L.S. N.S.W., vol. xli. p. 686, pl. 52, fig. 41.

Hab.—Old valves occasionally obtained at Carrum, Rye, Portsea, Port Phillip; dredged alive Western Port.

Obs.—Mr. Hedley has figured this species for the first time.

Genus **Marcia**, H. and A. Adams, 1857.

MARCIA NITIDA, Quoy and Gaimard.

1835. Venus nitida, Quoy and Gaimard. Astrolabe Zool., vol. iii., p. 529, pl. 84, fig. 13, 15 (in the text the figures are wrongly given as 13, 14).

1904. Chione nitida, Quoy and Gaimard. Hedley, P.L.S. N.S.W., vol. xxix., p. 194.

1906. Chione nitida, Quoy and Gaimard. Pritchard and Gatliff, P.R.S. Vic., vol. xviii, (New Series). p. 67.

1909. Marcia fumigata, Sowerby. Jukes-Browne, P. Mal. Soc. Lond., vol. viii., p. 237, 244.

1914. Marcia fumigata, Sowerby. Jukes-Browne, P. Mal. Soc. Lond., vol. xi., p. 88.

1917 Marcia nitida, Quoy and Gaimard. Hedley, P.L.S. N.S.W., vol. xli., 1916, p. 691, pl. 46, figs. 2, 3.
1917. Marcia nitida, Quoy and Gaimard. Chapman and Gabriel, P.R.S. Vic., vol. xl. (New Series), p. antea.

Hab.—Common in Port Phillip; Portland.

Obs.—Jukes-Browne has reviewed somewhat exhaustively the Family Veneridae, and has made Adams' Chione, subgen. Marcia into a genus.

DOSINIA GRATA, Deshayes. (Pl. iii.).

1853. Dosinia grata, Deshayes. Cat. Brit. Mus. Biv. p. 8.
1858. Dosinia grata, Deshayes. Adams' Genera, vol. ii., p. 431.
1862. Dosinia grata, Deshayes. Römer, Mon. Dosinia, p. 19.
1868. Dosinia grata, Deshayes. Pfeiffer, Malak, Blatt, vol. xv., p. 146.
1897. Dosinia grata, Deshayes. Tate, T.R.S.S.A., vol. xxi., p. 47.
1913. Dosinia grata, Deshayes. Hedley, P.L.S. N.S.W., vol. xxxviii., p. 270.

Hab.—Dredged 5 to 8 fathoms, Western Port; also dredged off Portsea, Port Phillip.

Obs.—A left valve, 30 x 40 mm. was forwarded to Mr. T. Iredale, London, for comparison with types, and he writes: "Agrees exactly with the types in the British Museum of *Dosinia grata*, Deshayes . . . from Tasmania, collected by R. Gunn. . . Tate and May (p. 429), place *D.grata*, Deshayes, as a synonym of *D.circinaria*, Deshayes, which it is not, types compared."

Much confusion has arisen respecting this species, and to Australian conchologists its identification has been perplexing, owing in the first place to Tate giving a wrongful figure,[1] and at the same time quoting D.diana, Adams and Angas, as a synonym. In 1897—reference above given—he corrected this, stating: "The type of *D.diana*, Adams and Angas, and the shell I figured as *D.grata* are certainly the same, but they are different from *D.grata.*" Tate and May[2] cited the species as a synonym of *D.circinaria*, Deshayes, from

1 D. grata, Deshayes. Tate, T.R S, S.A., vol. ix., 1886 (1887), p. 93, pl. v., fig. 15.
2 P.L.S., N.S.W., vol. xxvi., 1901, p. 429.

which it may be distinguished by its sharp, erect, concentric lamellae. We are indebted for the kindness of Mr. F. Chapman. He photographed the identified shell figured on Plate III.

SPISULA TRIGONELLA, Lamarck.

1818. Mactra trigonella, Lamarck, An. s. Vert., vol. v., p. 479.

1853. Gnathodon parvum, Petit. Jour. de Conch., vol. iv., p. 358, pl. 13, fig. 9, 10.

1903. Spisula parva, Petit. Pritchard and Gatliff, P.R.S. Vic., vol. xvi. (New Series), p. 108.

1914. Mactra (Spisula), parva, Petit. Smith, P. Mal. Soc. Lond., vol. xi., p. 146.

1914. Mactra, trigonella, Lamarck. Lamy, Bull, Mus. Nat. Hist., p. 245.

1915. Spisula (Hemimactra), parva, Petit. Chapman, Geol. Surv. S. Aust., Bull, No. 4, p. 50.

1916. Mactra trigonella, Lamarck. Hedley, J.R.S., W. Aust. vol. i., for 1915, p. 20.

1917. Spisula trigonella, Lamarck. Hedley, P.L.S. N.S.W., vol. xli., 1916, p. 692.

1917. Spisula trigonella, Lamarck. Chapman and Gabriel, P.R.S. Vic., vol. xl. p. antea.

Hab.—Coast generally.

Obs.—Spisula parva is reduced to synonymy through the discovery of an earlier Lamarckian appellation. Dr. Lamy declares their specific identity.

LASAEA AUSTRALIS, Lamarck.

1818. Cyclas australis, Lamarck. Anim. s. vert., vol. v., p. 560.

1842-1856. Cyclas australis, Lamarck. Hanley, Cat. Recent Biv. Shells, p. 90.

1913. Cyclas australis, Lamarck. Lamy, Bulletin du Mus. d'Hist. nat. Paris, p. 466.

1914. Lasaea scalaris, Philippi. Gatliff and Gabriel, V.N. vol. xxxi., p. 84.

1915. Lasaea australis, Lamarck. Hedley, P.L.S. N.S.W., vol. xxxix., p. 702.

1916. Lasaea australis, Lamarck. Hedley, Jour. Roy. Soc. Western Australia, vol. i. for 1915, p. 13.

Hab.—Coast generally.

Obs.—A very variable shell. Lamarck's vol. v. is paged to 560, and then the pages following are again numbered 551 to 560. L. australis occurs on the first of the pages that are numbered 560.

Genus **Brachydontes,** Swainson, 1840.

BRACHYDONTES EROSUS, Lamarck.

1819. Mytilus erosus, Lamarck, Anim, s. Vert., vol. vi., p. 120.

1906. Mytilus erosus, Lamarck. Pritchard and Gatliff, P.R.S., Vic., vol. xviii. (New Series), for 1905, p. 69.

1916. Brachyodontes erosus, Lamarck. Hedley, Jour. Royal Soc., Western Australia, vol. i., for 1915, p. 9.

Hab.—San Remo; Polwarth Coast; Portland.

BRACHYDONTES (HORMOMYA) HIRSUTUS, Lamarck.

1819. Mytilus hirsutus, Lamarck, Anim, s. Vert. vol. vi., pt. 1, p. 120.

1904. Mytilus hirsutus, Lamarck. Pritchard and Gatliff, P.R.S. Vic., vol. xvii (New Series), p. 248.

1905. Brachyodontes (Hormomya) hirsutus, Lamarck. Jukes-Browne, P. Mal. Soc. Lond., vol. vi., p. 223.

Hab.—Polwarth Coast; Kilcunda.

BRACHYDONTES (HORMOMYA) ROSTRATUS, Dunker.

1856. Mytilus rostratus, Dunker. P.Z.S. Lond., p. 358.

1904. Mytilus rostratus, Dunker. Pritchard and Gatliff, P.R.S., Vic., vol. xvii. (New Series), p. 247.

1905. Brachyodontes (Hormomya) rostratus, Dunker. Jukes-Browne, P. Mal. Soc., Lond. p. 223.

1916. Brachyodontes rostratus, Dunker. Hedley, Jour. Royal Soc. Western Australia, vol. i., for 1915, p. 10.

Hab.—Coast generally.

MODIOLA PULEX, Lamarck.

1819. Modiola pulex, Lamarck, Anim. s. vert., vol. vi., p. 112.

1904. Modiola ater, Zelebor. Pritchard and Gatliff, P.R.S. Vic. vol. xvii (New Series), p. 249.

1913. Modiola pulex, Lamarck. Hedley, P.L.S. N.S.W., vol. xxxviii., p. 265.

1914. Modiola pulex, Lamarck. Hedley, *Id.* vol. xxxix., p. 698, pl. 79, f. 24.

1916. Modiola pulex, Lamarck. Hedley, Jour. Royal Soc. Western Austr. vol. i., for 1915, p. 10.

Hab.—Coast generally.

Obs.—Mr. Hedley noted the types of this species in the Lamarckian collection of the Geneva Museum. His figure (cited above) is drawn from a specimen obtained at Frederick Henry Bay, Tasmania, and is Mytilus crassus, T. Woods, which becomes a synonym.

Genus **Notomytilus,** Hedley, 1916.

NOTOMYTILUS RUBRA, Hedley.

1904. Philippiella rubra, Hedley. P.L.S. N.S.W., vol. xxix., p. 207, pl. 10, figs. 44-47.

1906. Philippiella rubra, Hedley. Prichard and Gatliff, P.R.S. Vic., vol. xviii. (New Series), p. 69.

1916. Notomytilus rubra, Hedley. Aust. Ant. Exped. Zool. p. 20.

Hab.—Dredged in about 7 fathoms, Western Port, off Phillip Island; Portsea, Port Phillip; Torquay.

Obs.—This species is selected by Hedley for the type of his new genus Notomytilus. He states that his previous classification of it was made "under a misapprehension of the original diagnosis."

NOTOMYTILUS CRENATULIFERA, Tate.

1892. Myrina crenatulifera, Tate. T.R.S. S.A., vol. xv., pt. 2, p. 131, pl. 1, figs. 11, 11a.

1904. Philobrya crenatulifera, Tate. Pritchard and Gatliff, P.R.S. Vic., vol. xvii., p. 255.

1904. Philippiella crenatulifera, Tate. Hedley, P.L.S. N.S.W., vol. xxix., p. 208.

1906. Philippiella crenatulifera, Tate. Pritchard and Gatliff. P.R.S. Vic., vol. xviii. (New Series), p. 69.

1916. Notomytilus crenatulifera, Tate. Hedley, Aust. Ant. Exped. Zool. p. 20.

Hab.—Barwon Heads (type); Flinders, Western Port.

EXPLANATION OF PLATE III.

Dosinia grata, Deshayes.

The smaller figures are taken from the shell identified with the type.

All figures natural size.

[Proc. Roy. Soc. Victoria, 30 (N.S.), Pt. I., 1917].

Art. V.—*New or Little-known Victorian Fossils in the National Museum.*

Part XXI.—Some Tertiary Cetacean Remains.

By FREDERICK CHAPMAN, A.L.S., &c.
(Palaeontologist, National Museum, Melbourne).

(With Plates IV. and V.).

[Read 12th July, 1917].

Introduction.

The following notes embrace descriptions of teeth of two new cetaceans, one of which is a second Australian species of the extinct genus of sperm whales, *Scaldicetus*, namely, *S. lodgei*. The other form is a tooth referred to the living genus *Steno*, a dolphin which, so far as I am aware, has not been previously noted in the fossil condition. Both types are from the Lower Pliocene or Kalimnan series.

A new locality is given for the tooth of the great sperm whale, *Physetodon baileyi*, whilst an incisor of the squalodont genus, *Parasqualodon*, is newly recorded from Leigh River, near Shelford, an occurrence which helps to confirm the Miocene age of these particular beds.

Probably the most interesting cetacean discovery from a distributional point of view is the occurrence in the Victorian Kalimnan (Lower Pliocene) series, of Owen's ziphoid species, *Mesoplodon compressus*. This genus of beaked whales is already represented in the Victorian Janjukian (Miocene) beds by the strap-shaped tooth of *Mesoplodon geelongensis*, McCoy sp. Cranial rostra belonging to several species of *Mesoplodon* are also found in the Pliocene of England, Belgium and Italy, and about eight species still exist. Until the present occurrence, the rostra of this genus were only known in the fossil condition from the northern hemisphere, but six of the species now found living have their habitat in the Southern Ocean and adjacent seas.

The following remarks on the genus *Mesoplodon* by Prof. Flower have an especial interest to students of Australian recent and fossil cetacea[1]: "The geographical distribution of the group has a very great interest in relation to that of many other Australian groups, both of vertebrates and invertebrates. Among the earliest known re-

1 Trans. Zool. Soc. Lond., vol. x., 1878, p. 436.

mains of Cetacea, in the Belgian and Suffolk Crag, *Mesoplodon*, and closely allied forms are most abundant. Up to a little more than ten years ago the few stray individuals of *M.bidens* occasionally stranded on the shores of North Europe were supposed to be their sole survivors. Since that time it has been proved that they are still numerous in species, and even in individuals (as many as twenty-five of *M.grayi* having been stranded on one occasion on the Chatham Islands, and four at another time on the New Zealand coast, where it is sufficiently abundant and well known to have obtained the local name of Cow-fish), in the seas which surround the Australian continent, extending from the Cape of Good Hope on the one side to New Zealand on the other, though beyond these limits no specimens have yet been met with. It is the history of the Marsupial Mammals, of *Ceratodus*, of *Terebratula* [*Magellania*], and of numerous other forms.''

Systematic Description.

Order CETACEA. Sub-Order ODONTOCETI.

Fam. PHYSETERIDAE. Sub-fam. PHYSETERINAE.

Genus Physetodon, McCoy.

Physetodon baileyi, McCoy.

Physetodon baileyi, McCoy, 1879, Prod. Pal. Vict., dec. VI., p. 19, pl. LV., figs. 1, 2. Lydekker, 1887, Cat. Foss. Mammalia, Brit. Mus. (Nat. Hist.), pt. V., p. 57.

Observations.—A portion of the tooth of the above species of extinct sperm whale has lately been donated to the Museum collection from a new locality in the Kalimnan series, viz., Grange Burn (Forsyth's), near Hamilton. It represents the apical portion of the tooth, about one-half of the entire length, and measures 132 mm. in length. At its widest part its measurement is exactly the same as the original specimen described by McCoy, which came from the Kalimnan of Beaumaris, so that it may be assumed that both individuals reached their maximum development before their demise.

The osteodentine around the pulp cavity shows the same spheroidal grouping of the dentinal layers round the vascular centres as in the earlier described specimens. The fracture at the proximal end of the specimen occurs near the junction of the osteodentine with the dentine proper. The cement is 14 mm. thick at 10.50 cm. from the apex.

Occurrence.—Tertiary (Kalimnan series). Grange Burn, near Forsyth's, Hamilton. Collected and presented by the late Lieutenant Edward Ellis Henty.

Genus **Scaldicetus**, Du Bus.

Scaldicetus lodgei, sp. nov. (Plate IV., Fig. 6).

Description.—Tooth, long, slender, conical, gently curved, especially in the apical portion. Pulp cavity open, narrow and apparently not very deep. The cement is smooth, but marked with microscopically fine longitudinal lines and cracks; it extends for 76.5 mm. from base of enamel cap down to the root, and is of a rather pale ochreous brown. The cement is corroded or eaten away in large patches, and the exposed dentine is encrusted in places with a nubecularian foraminifer, and there is also a valve of *Dimya* sp. attached to the surface of the root. The enamel cap, of a warm sienna brown colour, is longitudinally grooved and crenulated, but the relief is not so granulate as in the tooth of *S.macgeei*, Chapman.[1] Where the enamel is fractured the apex shows the dentine to be compact, semi-vitreous and dark brown in colour, weathering to ochreous.

Measurements.—Tooth, present length, 102.5 mm.; portion of apex missing, circ. 2 mm. Length of enamel cap when complete, cir. 15 mm. Diameter of tooth at base of enamel cap, 8 mm.; greatest diameter of root (at 23 mm. from base), 20.5 mm.; diameter of pulp cavity at base, 10 mm.

Weight.—The tooth referred to the above species weighs $1\frac{1}{2}$ oz., or .104 kilogrammes. That of *Scaldicetus macgeei* weighs 6 oz. 2 dwts., or .423 kilogrammes. The largest tooth of the genotype, *S.carreti*, weighs $1\frac{1}{2}$ kilogrammes.

Observations.—In comparing the tooth of *Scaldicetus lodgei* with that of the previously described *S.macgeei*, the following salient differences are noted :—

S. lodgei.	*S. macgeei.*
Crown one sixth of entire length.	Crown one third of entire length.
Enamel cap finely striated and crenulate.	Enamel cap rugosely vertically striated.
Apex of crown sharply conical.	Apex of crown broadly conical.
Root gradually widening to near base and then contracting.	Root widening rapidly to base.
Pulp cavity narrow, opening eliptical.	Pulp cavity large, open and subcircular.
Weight, .104 kilos.	Weight, .423 kilos.

From the two previously described species of *Scaldicetus*, the present form, *S.lodgei*, differs very markedly in its slender shape

1 Records Geol. Surv. Vict., vol. iii., pt. ii., 1912, p. 236, pl. xl.

and small size. The build of both *S.carreti*, Du Bus (Antwerp Crag) and *S.macgeei*, Chapm. (Beaumaris), is heavy, and the form of the teeth broadly conical. The present tooth of *S.lodgei* is that of a mature individual, and it does not in any of its characters suggest specific affinity with the Beaumaris species. As in *S.lodgei*, the Belgian species has the enamel of the crown longitudinally striated, whereas in *S.macgeei* the enamel is not only rugosely striated, but beaded or crenulate.

Occurrence.—Balcombian or Oligocene. Muddy Creek (Clifton Bank), near Hamilton, Victoria.

This tooth (holotype) was discovered by the late Mr. H. Lodge, of Hamilton, and we are indebted to Mr. F. P. Spry for presenting this interesting specimen to the National Museum.

Note.—According to the label, it was found at "Muddy Creek, near Hamilton." Since the locality is often used in a general sense by collectors for several geological exposures in the district, including the Kalimnan of the Grange Burn, it suggested the possibility of the tooth having come from the latter locality. However, this doubt is removed by an examination of the material enclosed in the pulp cavity of the tooth, which contained typical upper Clifton Bank foraminiferal sand with shells of the pteropod *Vaginella*, and rolled and wind-polished *Amphisteginae*. It is, therefore, conclusive that the tooth was found in *Vaginella* band at Clifton Bank, which includes the higher Balcombian horizon merging on the Janjukian bed represented in the Grange Burn area by red limestone.[1]

Sub-fam. Ziphiinae.

Genus **Mesoplodon**, Gervais.[2]

Mesoplodon compressus, Huxley sp. (Plate IV., Figs. 1-4 ; Plate V., Figs. 7-11).

Belemnoziphius compressus, Huxley, 1864, Quart. Journ. Geol. Soc., vol. XX. p. 388, pl. XIX.

Ziphius compressus, Owen, 1870, Crag Cetacea, No. 1 (Ziphius), Mon. Pal Soc., vol. XXIII. p. 25 ; pl. V., fig. 3.

Mesoplodon compressus, Huxley sp., Lydekker, 1887, Cat. Foss. Mammalia, Brit. Mus., pt. V., p. 73. Woodward and Sherborn, 1890, Cat. Brit. Foss, Vertebrata, p. 363.

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1 See Mem. Nat. Mus. Melbourne, No. 5, 1914, p. 44, fig. 14.

2 For notes on the validity of this generic term see Flower, W. H., Trans. Zool. Soc., vol. viii., 1872, p. 208, footnote 3, and Idem, ibid., vol. x., 1878, p. 434.

Observations.—*Mesoplodon* agrees with the other beaked whale, *Ziphius* (of which there is probably only one living species), in having an ossified mesethmoid, but the nasals joined together form the vertex of the skull in the latter genus. In *Hyperoödon*, the bottle-nosed whale, there are large longitudinal crests on the maxillae at the base of the rostrum. In *Berardius* the mesethmoid is only partially ossified. *Choneziphius* has the mesethmoid cartilage non-ossified, and there is a fistular cavity throughout the short, thick rostrum. According to Flower, the tympanic bone of *Berardius* is exactly like that of Mesoplodon.[1]

The chief character given by Owen for the cranial rostrum in the species *compressus* is "the predominance of the dimensions of depth over that of breadth at every part of the extent of the specimen figured." Prof. Owen also states that "the pre-frontal mid-tract is transversely convex from its beginning, the convexity increasing as it advances; and, from the low position of the ecto-maxillary ridges and the steep slope thereto of the premaxillaries, the mid-tract seems, of itself, to constitute the upper surface of the rostrum." In Huxley's specimen the same character of great vertical depth prevails, with the exception of the extreme posterior, where it is wider than deep. This exception would also most likely have obtained in Owen's specimen, but for the fact that the posterior area adjacent to the narial openings is wanting.

The only apparent differences between Huxley's and Owen's specimens are that, in the former, the sectional outline is more distinctly rhomboid, and there is a slit in the mesethmoid band "about 2¼ in. in front of the upper apertures of the canals," . . . . "which deepens as it passes backward and becomes lost in an irregular fossa." This median slit is not present in the nearly perfect Australian specimen from Grange Burn, so that in this point it agrees with Owen's example. On the other hand, another specimen from Grange Burn, which is in Mr. Dillwell's collection at Hamilton, and of which there are casts in the National Museum, shows a distinct median slit, as in the Huxley example, and much longer, measuring 4¾ in. The two Grange Burn specimens have been carefully examined and measured, with a view to discovering any definitely separable characters, but with the result that one feels bound to conclude that the slight differences between them represent merely individual variation, such as are evident in living species of this genus. For example, the median slit probably representing a vesti-

1 Flower. Ibid., vol. x., 1878, p. 423.

gial line of imperfect ossification, or even infilling of a hollow vomerine, as met with in *Choneziphius*, may be wholly obliterated in some examples and not in others; whilst abrasion may have something to do with its absence, since all fossils from the nodule beds are more or less rolled and worn.

The sectional drawing of the rostrum of "*Belemnoziphius compressus*," given by Prof. Huxley, is so nearly like that of Owen's "*Ziphius compressus*," the former being more angular in outline than the latter, but generally agreeing with the Grange Burn specimens in general contour, that it is impossible to point to a specific difference between all three occurrences. The interesting point to note, however, is that the more perfect rostrum from Grange Burn, with its smoother posterior mid-tract, agrees more closely with Owen's example; whilst the less perfect Grange Burn specimen, with its fissured mid-tract, agrees more nearly with Huxley's specimen. Apart from a consideration of morphological and structural differences in these Australian specimens, the fact that they occur together in the same geological horizon, would lend support to the assumption that, being otherwise so closely allied, they were specifically identical.

Description of examples of Mesoplodon compressus, Huxley sp. from Grange Burn.

Specimen A. *Description.*—A well preserved cranial rostrum. In this specimen the pre-frontal mid-tract rises prominently above the upper surface of the rostrum; it is at first (proximally) flatly convex, becoming more strongly arched towards the middle of the rostrum and again depressed in the anterior third. This mid-tract is proportionally narrow as compared with some other described forms, as *Mesoplodon longirostris*, Cuvier sp.[1], and differs from that species in the absence of the deep, longitudinal sulcus. The upper median surface of the rostrum rises and falls in two low curves from the base to the tip of the snout, the greatest convexity being situated a little in front of the middle of the rostrum. The rostrum is slender and gently tapering, and is deeper than wide along the entire length excepting in the pre-frontal area, where the depth is less than the width. A transverse section of the rostrum in any part of the middle and anterior thirds gives a laterally compressed hexagonal figure, whilst that from the pre-frontal region is trapezoidal in outline, not unlike that of *M. tenuirostris*, Owen sp.[2]

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1 *Ziphius longirostris*, Cuvier, Ossemens Fossiles, 2nd ed., vol. v., pt. i., 1823, p. 357. *Ziphius medilineatus*, Owen, Crag Cetacea (Mon. Pal. Soc.), 1870, p. 22, pl. iv., fig. 3. *Mesoplodon longirostris*, Cuv. sp., Lydekker, Cat. Foss. Mamm. Brit. Mus., pt. v., 1887, p. 68, fig. 13.

2 *Ziphius tenuirostris*, Owen, op. cit., 1870, p. 24, pl. v., figs. 1, 2. *Mesoplodon tenuirostris*, Owen sp., Lydekker, op. cit., 1887, p. 71.

The narial orifices are situated in a concavity of the extended premaxillae, the left being not so long as the right. The nervo-vascular foramina of the interorbital area of the maxillary are slightly in advance of the narial openings, and lead downward and backward to the ent-orbital foramina. The vomerine is visible on the inferior surface of the rostrum as a narrow lenticular wedge about 90 mm. long and 9 mm. broad in the widest part.

In a cavity of the premaxillary on the right side of the rostrum, about 41 mm. from the anterior, there occurs, embedded in the hardened and phosphatized mud, a small tooth of a depressed conical shape, slightly curved and bluntly pointed, having a length of 4 mm. and a width of 2.5 mm.[1]

Measurements.—Total length of complete rostrum, 49.5 cm. Width on a tranverse line through middle of antorbital foramina, 12.6 cm. Width at 10 cm. from base, 62 mm.; depth, 80 mm. Width at 20 cm. from base, 54 mm.; depth, 61 mm. Width at 30 cm. from base, 39 mm.; depth, 46 mm. Width at 20 mm. from apex, 21 mm.; depth, 23 mm. Distance between narial openings, 31 mm. Distance between antorbital foramina, 82 mm. Width of mesethmoid band at 75 mm. from base, 23 mm.

Specimen B. *Description.*—This is a less perfect example than the foregoing, the rostrum having lost about one-half of the anterior portion, and the lateral edges of the maxillaries in the pre-frontal region. The characters of this specimen compare closely with the foregoing. The slope on either side of the mesethmoid ridge is steep as in the previous specimen, but the surface is more convexly rounded and the ecto-maxillary ridge less prominent. The inner margins of the narial openings are 21 mm. apart as against that of Spec. A, in which they are 32 mm. apart. Specimen B, however, is proportionately smaller in every respect, and either represents a mature individual of different sex from Specimen A, or is a younger example.

Measurements.—Length of rostrum (incomplete), 25.5 cm. Width on a transverse line through middle of antorbital foramina (incomplete expanse), 9.4 cm. Width at 10 cm. from base, 61.5 mm.; depth 90 mm. Width at 20 cm. from base, 43 mm.; depth, 59 mm.

Relationship of M. compressus with living species.

According to Professor Sir W. H. Flower there are eight existing species of this genus, all of which, as that author says,

1 The structure of the tooth in *Mesoplodon sowerbii* (=*M. bidens*) has been described by E. Ray Lankester in Trans. R. Microsc. Soc. (n.s.), vol. x?, 1867, p. 55. See also Flower, W. H. Trans. Zool. Soc., vol. viii., 1872, p. 223, for description of tooth of *Berardius arnouxi*.

"have a close generic resemblance. *Mesoplodon bidens*, Sowerby sp., is common to the North Sea and North Atlantic; *M.europaeus*, Gervais, sp., was found in the English Channel; *M.densirostris*, Blainville sp., occurred off the Seychelles Islands, South Africa, and Lord Howe Island; *M.layardi*, Gray sp., was found off the Cape of Good Hope, near Sydney, New Zealand and the Chatham Islands; *M.hectori*, Gray sp., found in Titai Bay, New Zealand; *M.grayi*, Haast sp., from Bank's Peninsula, New Zealand; *M.haasti*, Flower, North Island, New Zealand; and *M.australis*, Flower, from Lyall Bay, New Zealand.

In certain structural characters of the cranial rostrum, the relationships of the fossil, *M.compressus*, judging from the Australian specimens, lie nearest to *M.grayi*, Haast sp., from New Zealand,[1] chiefly by the indications of a row of small teeth in the upper jaw, as well as by the deep lateral basirostral groove, and the posterior position of the premaxillary foramen in relation to the maxillary. In the sectional sketches of rostra of living species of *Mesoplodon* by Flower,[2] that of *Mesoplodon haasti* is almost identical both with those given by Huxley and Owen respectively, as well as some taken from the above described Victorian specimens. In regard to the supposed identity of *M.grayi* and *M.haasti*, by Von Haast, who included them under the one species name of *M. grayi*, Flower remarks[3]: "Making every allowance for individual variation, it scarcely seems possible that a rostrum such as that shown in Fig. 2, could change in the course of growth to that of Fig. 3. If so, most of the determinations of the fossil species based solely upon the form of the rostrum are quite valueless."

Occurrence.—The discovery of two Australian fossil specimens of a ziphoid whale identifiable with a species occurring in the Crag deposits of England is especially interesting to stratigraphists, since it further confirms the identification of the Victorian Kalimnan beds with the Pliocene of England and Belgium. Specimen A of the foregoing descriptions was received by exchange from Mr. R. Hughan, whilst Specimen B is a cast taken from a fossil in Mr. Dillwell's collection. They are both from the Kalimnan (Lower Pliocene) of Grange Burn, near Hamilton.

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1 See synopsis of characters of *Mesoplodon* by Flower, Trans. Zool. Soc., vol. x., 1878, p. 418.

2 Op. cit., p. 422, figures.

3 Flower, op. cit., vol. x., 1878, p. 422.

Note on "*Ziphius (Dolichodon), geelongensis,*" McCoy.[1]

The fossil from Waurn Ponds referred by Sir F. McCoy to a ziphioid is a long, strap-shaped tooth, having a compressed oval sectional outline, and an extensive but slender pulp cavity. It is compared with a type of tooth seen in *Mesoplodon layardi* (found off the Cape of Good Hope, Chatham Islands and New Zealand), in which the pair of mandibular teeth have a crown composed of true dentine surmounted by a small and pointed enamel cap. The crown is raised upon a solid mass of osteo-dentine, which has a continuously changing form as the tooth advances in growth, tending upwards, backwards, and finally inwards.[2] In course of time these teeth interlock over the top, preventing complete opening of the jaws. Their great size and recurved form is curiously paralleled in the sabre-toothed tigers, as remarked by Beddard.[3]

The existing *M.layardi*, Gray sp., and, presumably, *M.geelongensis*, McCoy sp., belong to the genus *Mesoplodon* sensu stricto, while *M. compressus*, Owen sp., is referable, according to Flower, to the group *Dioplodon*, including *M.densirostris*, Blainv, sp., *M.australis*, Flower, *M.grayi*, Fl, and *M.haasti*, Fl.

Fam. SQUALODONTIDAE.

Genus Parasqualodon, T. S. Hall.

Parasqualodon wilkinsoni, McCoy sp.

Squalodon wilkinsoni, McCoy, 1875, Prod. Pal. Vict., dec. 2, p. 7, pl. XI., Figs. 1*a-d*. Id., ibid., 1879, dec. 6, p. 20, pl. LV., Figs. 3, 3*a*, *b*.

Prosqualodon wilkinsoni, McCoy sp., T. S. Hall, 1911, Proc. R. Soc., Vict., vol. XXIII., N.S. pt. II., p. 262, pl. XXXVI., Figs. 1-5.

Observations.—In Dr. Hall's paper, "On the Systematic Position of the species of *Squalodon* and *Zeuglodon* described from Australia and New Zealand," a specimen (No. 5529) in the National Museum from Waurn Ponds is figured. This is noticed by Hall as an "Incisor of (?) *Parasqualodon wilkinsoni.*" Having recently examined the cetacean teeth in the Museum in some detail for the purpose of the present paper, I have arrived at the conclusion that this specimen is without doubt referable to the above species, and that the curious appearance of an incision at the base of the crown as shown

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1 Prod. Pal. Vict., dec. 7, 1882, p. 23, pl. lxix.
2 See Flower, op. cit., vol. x., 1878, p. 418.
3 Cambridge Nat. History. Mammalia, 1902, p. 369.

in the photograph by Dr. Hall, is due to an interesting mineralogical change set up in the tooth during early fossilisation and subsequent weathering. The narrower root axis as compared with the crown is caused by phosphatization of the dentine and its consequent hardening, whereas the surrounding cement, being of a softer texture, has subsequently been removed by the resortment and disturbance of the deposit before final sedimentation. The surface of the phosphatized axis of the tooth is polished like that of the mineralized tympanic bones found associated in the same beds. The grooved ornament of the enamel of the crown of the tooth is exactly similar to typical incisor teeth of *P. wilkinsoni*.

Occurrence.—Tertiary (Janjukian.) Waurn Ponds, near Geelong. Presented by the Rev. C. S. Y. Price.

A new locality for *P. wilkinsoni* may here be noticed, namely Leigh River, near Shelford, where a fairly complete incisor was found and presented to the National Museum by Mr. J. H. Young, of Meredith. This discovery of a typical Miocene species helps to correlate the Shelford beds with the Janjukian series.

Fam. DELPHINIDAE.

Genus Steno, Gray.

Steno cudmorei, sp. nov. (Plate IV., Fig. 5).

Description.—Tooth, convexly curved and twisted, more or less circular in section. Root more than twice the length of the crown, closed at the base and swollen or bulbous just below the base of the crown. Crown conical, curved, with a moderately sharp apex; colour dark brown increasing in depth to black at the base; surface roughly scored by fine irregular vertical furrows. The cementum impinges over the base of the crown, and at 2.5 mm. below the crown is cinctured by a brown stain, probably marking the upper edge of the alveolus. The root is ochreous brown to yellow, and irregularly wrinkled and furrowed, especially towards the base.

Measurements.—Length of tooth, measured along the outer side, 23 mm. (crown 7 mm.; root, 16mm.); width of crown at base, 4 mm.; widest part of root, near distal end, 5 mm.

Observations.—At first glance this tooth might be thought to show alliance with the incisor of *Parasqualodon*, which it resembles in general shape and in the vertically rugose crown. The root in the present tooth, however, is closed, whilst that of the incisor of *Parasqualodon* is open and deep. Further than this, *Parasqualodon* has

the crown nearly, if not quite, equal in length to the root, and the enamel furrows are sharply ridged and not vermiculate, as in the above species.

The smaller and slender character of the tooth and the closed root resembles that of the Dolphin family, and comparison was made with *Delphinus uncidens*, Lankester,[1] which, although having the peculiar twisted and swollen shape of the root of the Beaumaris tooth, has the enamel of the crown finely and sparsely furrowed. Turning, then, to Prof. Flower's classical paper "On the Characters and Divisions of the Family Delphinidae,"[2] we read that the genus *Steno*, which is represented by *S. rostratus*, Cuvier sp., and found in the Atlantic, Indian and Pacific Oceans, and in the Red Sea, is distinguished from other genera of this family by the furrowed character of the teeth :—"Teeth, 21 to 25 on each side of the jaw, of comparatively large size (5-6 millims at base of crown),[3] and in most, if not all the species, with their surfaces roughened by fine, irregular longitudinal grooves (which are in a great measure effaced in old individuals), not seen in other Dolphins, and whence the name *Glyphidelphis* proposed by Gervais for the section."[4]

Occurrence.—Tertiary (Kalimnan), Lower Pliocene. Beaumaris, Port Phillip. Found by Mr. F. A. Cudmore, after whom it has been named, and who presented it to the National Museum.

EXPLANATION OF PLATES.

Plate IV.

Fig. 1.—*Mesoplodon compressus*, Huxley sp. Cranial rostrum, viewed from above. Specimen A. Tertiary (Kalimnan.) Grange Burn, near Hamilton, Victoria. About $\frac{2}{7}$ natural size.

Fig. 2.—*M. compressus*, Huxley sp. Cranial rostrum, viewed from the side. Specimen A. About $\frac{2}{7}$ natural size.

Fig. 3.—*M. compressus*, Huxley sp. Cranial rostrum, viewed from below. Specimen A. About $\frac{2}{7}$ natural size.

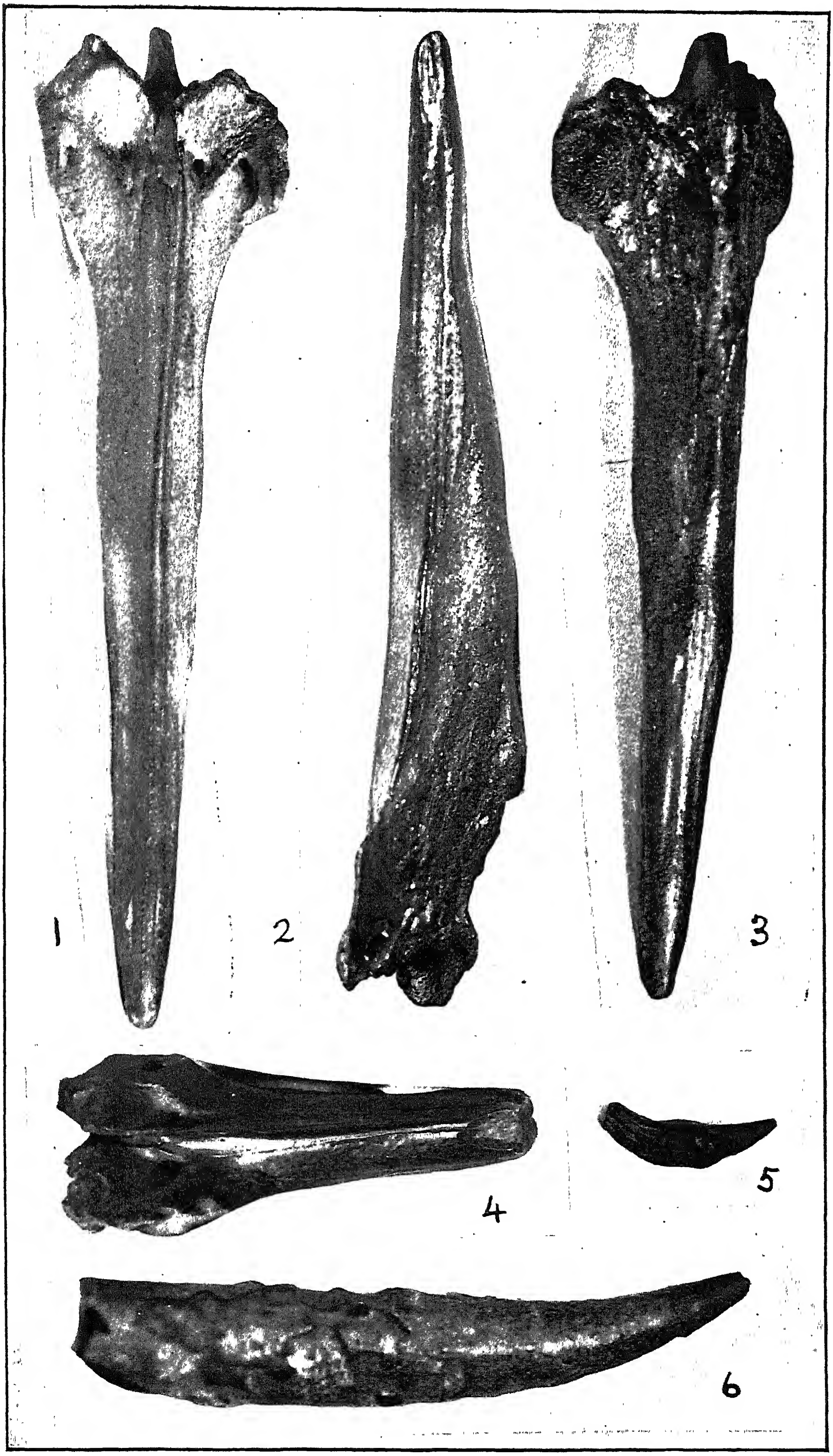
Fig. 4.—*M. compressus*, Huxley sp. Cranial rostrum, viewed from above. Specimen B. Same locality. About $\frac{2}{7}$ natural size.

1 Ann Mag. Nat. Hist, ser. 3, vol xiv, 1864, p. 356, pl viii, figs 12, 13. This tooth and otic bones have since been referred to the genus *Globicephalus*. See Lydekker. Cat. Foss Mammalia. Brit. Mus., pt. v., 1887, p. 81.

2 Proc. Zool. Soc. Lond, 1883, pp. 466-513.

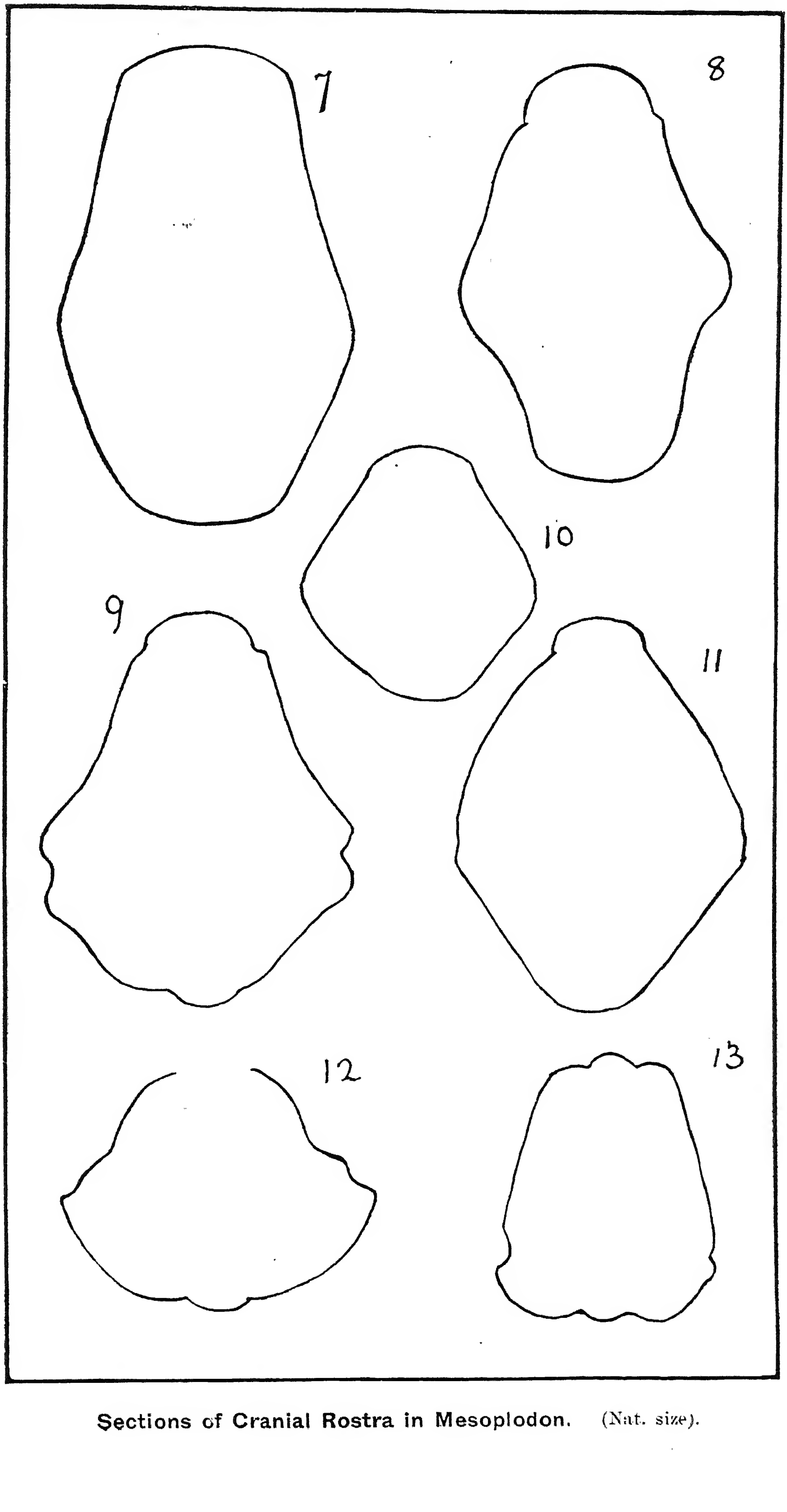
3 Width of crown in fossil specimen, 4 mm.

4 Op. supra cit., p. 482.



F.C., Photo.

Mesoplodon, Steno and Scaldicetus. Tertiary, Victoria.



Sections of Cranial Rostra in Mesoplodon. (Nat. size).

Fig. 5.—*Steno cudmorei*, sp. nov. Tooth. Tertiary (Kalimnan). Beaumaris, Port Phillip. About natural size.

Fig. 6.—*Scaldicetus lodgei*, sp. nov. Tooth, Tertiary (Balcombian). Clifton Bank, Muddy Creek, near Hamilton. Slightly under natural size.

PLATE V.

Fig. 7.—Sectional outline of Huxley's type of "*Belemnoziphius compressus*." From the Lower Pliocene of Suffolk, England. (After Huxley.)

Fig. 8.—Ditto of Owen's type of "*Ziphius compressus*." Lower Pliocene, Suffolk, Eng. (After Owen).

Fig. 9.—Ditto of Specimen A, *Mesoplodon compressus*, Huxley sp. taken at 22 cm. from distal end. Kalimnan (Lower Pliocene). Grange Burn, Victoria.

Fig. 10.—Ditto of Specimen A, taken at 12 cm. from the distal end.

Fig. 11.—Ditto of Specimen B, taken at 15 cm. from narial openings. Same locality.

Fig. 12.—Ditto of cranial rostrum of *Mesoplodon grayi*, Haast sp. (young). After Flower. Living.

Fig. 13.—Ditto of *M.haasti*. Flower. (adult). After Flower. Living.

All figures on this plate to actual scale.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. I., 1917].

ART. VI.—*Description of a New Dividing Engine for Ruling Diffraction Gratings.*

BY H. J. GRAYSON,

University of Melbourne.

(With Plates VI.–XVII.)

[Read 12th July, 1917].

Introductory.

The following pages comprise a description of a New Dividing Engine designed and constructed by the writer for the ruling of Diffraction Gratings and also, with certain modifications, of accurate scales. Prior to 1910, when this work was begun, a considerable experience of the difficulties inherent to work of a related character had already been obtained; particularly with respect to the ruling of very fine or closely spaced lines, known as "Test Rulings,"[1] used for testing the resolving and defining power of Microscope objectives. Rulings for this purpose, known as Nobert's Test Plates, were first made by Herr Nobert with the aid of a machine the design of which remained a carefully guarded secret until his death. On this machine he ruled his celebrated Diffraction Gratings, which were the first of their kind available for spectroscopic work.

Several papers,[2] descriptive and critical, referring to the author's earlier work, will serve to show that this fresh undertaking—the construction of a machine for ruling Diffraction Gratings—though far more difficult than anything of the kind previously undertaken by him, had at least a reasonable prospect of being successful, provided health permitted and suitable mechanical facilities were available.

For a time progress was somewhat slow, owing to lack of essential appliances and the very limited time available for so great an undertaking. Both these drawbacks were, however, largely overcome—mainly by an extension of the time available for construc-

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1 "The Microscope," Naegeli and Schwendener, 1889. Translation.

2 "A Wave-length Comparator for Standards of Length," by A. E. H. Tutton, M.A., D.Sc., F.R.S. Phil. Trans. Royal Soc. of London (Series A), vol. 210, pp. 1-34. "On the Measurement of Grayson's Ten-band Plate," by A. A. Eliot Merlin, Journ. R. Micro. Soc., 1910, pp. 5-8. "On the Measurement of Grayson's New Ten-Band Plate," by A. A. Eliot Merlin, Journ. R. Micro. Soc., 1911, pp. 160-163. "Comparative Micrometic Measurements, by Dr. Marshall D. Ewell, Journ. R. Micro. Soc., 1910, pp. 537-554. Also many "Notes" and "References" to Grayson's Rulings by E. M. Nelson, Esq., Journ. R. Micro. Soc., earlier vols.

tional work upon the machine, and also partly in that the undertaking was later recognised as a piece of "Research Work" under the regulations governing University Research Scholarships. The latter adjustment served to bring the work directly under the notice and control of the Professor of Physics, Dr. T. R. Lyle, F.R.S., to whom it was arranged that I should report from time to time. This served to make available additional mechanical facilities, and led to a transference of my services and work to the Department of Physics.

Preliminary Outline of the Design of the Machine.

It is desirable, before describing the more important parts of the machine, to outline its essential features. A fuller description of certain parts is also desirable, as published descriptions of similar machines frequently lack constructional details.

Even Professor Rowland's article, on the grinding of a precision screw, omits reference to important working details; while similar omissions occur in the published description of his ruling machine, issued at a much later date. Thus one frequently fails to find the information sorely needed when entering upon a similar undertaking. The omission of information, with respect to the working routine of these undertakings, may frequently mean the difference between success and failure, or, in any case, great lose of time and labour on the part of those who attempt similar work. Occasionally, even negative experiences are not without value, and are worth recording.

In the following preliminary description of the completed machine, reference to the plates and photographs, particularly Plates VI. to XVII., will be advantageous. For example, Plate VI. is a plan of the complete Engine drawn to scale. The various parts are numbered, and their general purpose and relationships are indicated in the descriptive index.

The bed of the machine, marked A, of cast iron, is a hollow rectangular oblong box, with several internal cross webs for increasing its rigidity. Plate VII., an end view photograph of the machine, shows the external outline of the bed. Externally, the bed has been accurately machined throughout; the top surface and one edge have also been ground true. This form of bed is very rigid in proportion to its mass, and is, moreover, not unwieldy to handle or complicated in outline; its weight, apart from any attachments, is under 70 lbs.

Attached to the outer faces of this simple form of bed are all the essential working parts of the machine, other than the driving mechanism, which is independent of the bed, apart from the necessary attachment to its base. This relationship is shown in Plate VII.

On the right hand half of the upper surface of the bed is the screw (1) with its supports (8), or capped bearings, which are bolted directly to the bed. The screw carries and operates the nut only, and is therefore practically free from any stress or strain other than what is due to a direct axial pull. The connection of the screw with the travelling carriage, supporting the plate to be ruled, is made through two steel bars (19), one on the right hand and the other on the left of the screw, and both parallel with it. These rods are screwed into a horizontally swivelling steel ring, surrounding the outer casing of the nut, and are rendered slightly flexible in a vertical plane by grinding them partly through near the point of attachment to the ring. The nut is therefore relieved from any stress other than the weight of the two rods and ring. The other ends of these rods are joined to a crossbar, and the latter to the carriage, through the agency of parts Nos. 18, 20 and 21, details of which will be found in the index to Plate VI.

The "pitch" of the screw is approximately 20 threads to the inch, or more exactly, 20 threads=.9997 in. at 62°F., and as it may carry one or other of two interchangeable and accurately cut ratchet heads with 360 and 540 teeth respectively, operated by double pawls, its ruling range varies from 20,000 lines per inch down, in to approximately 7200 lines per inch. The position of the ratchet heads, and mode of their attachment to the screw, is shown on the plan and index of the related parts.

The travelling steel nut is 3 inches long, and is lined with a special alloy, related to a bearing metal, in which the threads are cut. After cutting the threads, the nut was ground with oil only, under pressure, to a bearing fit upon a duplicate screw of identical pitch and thread form, and finally upon the permanent screw itself, thus ensuring a true bearing fit throughout. The steel casing of the nut is surrounded by an outer ring of steel, in which, in addition to the rods already described, is screwed a round steel lever (4), the further end of which carries a short revolving bar with hardened bearing surfaces sliding upon an optically true guide bar (13). This bar is adjustible with respect to its parallelism in relation to the screw axis, and can be used, if desired, for slight correction

of the pitch of the screw. This last adjustment is effected by means of two micrometer screws (15) seen in Plate VIII. Any elevation of the bar due to a reversed action of the screw and ratchet is obviated by a weight serving as a counterpoise and an upper guide bar (16). The nut has a clear run of nearly 7 inches upon the screw; this range of motion therefore represents the ruling capacity of the engine.

The thrust block (17) with its sapphire bearing face and several adjustments (7 and 7a), are important parts of the machine, which call for great precision in setting, which will be the subject of special mention later. The position of the thrust block is almost exactly central upon the bed of the machine. Hence, it is favourably situated with respect to any expansion of the bed due to temperature changes. The effect upon the ruling of such changes appears to be very slight, as seems to be proved by careful inspection of a 40 hours' ruling, during the progress of which temperature fluctuations amounting to 3°C. were recorded, but appeared to have produced no discoverable change in the regularity of the ruling.

The travelling carriage, which supports the plates while they are being ruled, is advanced by a central axial pull, directly in line with the screw axis, through the agency of the two rods already described, which serve to connect up the ruling carriage with the nut. The advantage of having screw, nut and ruling table joined together in a direct axial line is obvious, and, so far as I am aware, is an arrangement which has not hitherto been adopted in existing ruling engines.

The ruling table itself is simple, being merely a square plate of steel fitted with a detachable, circular graduated revolving super-table for supporting any rulings, or plates for such, requiring angular adjustment. The lower plate, serving as the base, is 6 inches square and $\frac{3}{8}$ in. thick. It slides, by means of semi-circular grooved supports, attached to its under surface, along two heavy circular rods of steel very accurately ground and polished, and resting in special supports screwed to the bed. The chief function of these two rods is to act as guides or ways for maintaining the exact alignment of the ruling carriage with the screw. Most of the weight of the ruling plate, and also of any load it may carry, is borne by a separate under carriage rolling with a minimum of friction directly upon the upper surface of the bed.

The frame and supports of the carriage are seen in outline on the plan as 27, 28 and 29. The under frame (27 and 28) supporting

the rods upon which the carriage slides to and fro, is best seen in Plate IX. It consists of two identically shaped strong brackets bolted to the bed, one on each side, which serve mainly to support two rectangular steel bars grooved on their upper surfaces, throughout their length, to the exact curvature of the two circular glass rods (29) which are ground perfectly straight and accurately uniform. These rods rest in, or rather float upon, a viscous medium (thick oil or vaseline) within the grooves of the two steel supports. The glass rods can be slightly adjusted to secure parallelism and alignment, by means of the four screws (30 and 31). Such adjustment is very slight, and made with only just sufficient pressure to prevent any longitudinal movement of the bars.

The chief effect of thus supporting the glass rods is the complete suppression of any tremour or vibration during movement of the diamond carriage over their surface. The surfaces themselves are not only ground, but are semi-polished, so that they consist essentially of innumerable minute facets, and when so prepared render the use of any lubricant unnecessary. It was found that the use of any lubricant would vary in its action, frequently introducing a variable load or pull upon the carriage during the progress of a ruling.

The diamond bearing carriage is seen detached in the plan (Plate VI.), and in various other aspects in the series of photographs illustrating the machine. It is a somewhat complicated piece of mechanism. Leaving to a later page its more detailed description, the following outline of its principal parts and movements will serve to make clear its general operation. The plan shows the outline of the carriage as a rectangular framework, which is built up of brass and steel parts (32, 33 and 34) supporting a superframe (35) carrying all the adjustments for raising and lowering those parts which control the movements of the diamond ruling point, situated at 40, during the operation of ruling a line. The chief adjustment in elevation is effected by means of a central screw (36) operating the dovetailed slide near 35. This slide carries all the parts 37-42.

The lower frame comprises the two broad bars (34) immediately over the glass guides (29). These bars are connected together by means of two steel plates (32, 33). The lower faces of the bars form rectangular grooves, and are fitted with boxwood linings adapted to the curvature of the glass rods upon which the frame slides to and fro. This motion is communicated to the carriage from the eccen-

tric drive (52) and transmitted to the frame through the driving rod (44). A second and smaller driving rod, not shown in the plan, lies immediately under 44, and is so adjusted as to move in the same direction, but slightly ahead of 44, thus raising or lowering the ruling point in advance of any movement of the frame by 44.

The sequence of movements in the ruling of a line is as follows:—The diamond is first lowered into contact with the surface of the plate to be ruled. This is effected by the falling of a bell-crank lever due to the withdrawal of the rod underlying 44. The rod (44) then draws the carriage slowly forward, through the interval determined by the position of the crank (53), and the line is completed. The first return movement, due to the revolution of 53, raises the diamond, through the lifting of the bell crank about .02 inch, above the ruled plate before any movement of the carriage on its ways can occur. The moment the diamond is clear the return journey of the carriage commences, and continues to the starting point of the next line; the diamond remaining suspended both during the return journey of the carriage and feed of the ratchet wheel which occur at the same time. The several movements ars so timed and adjusted as to permit the longest stationary interval to be precedent to the lowering of the diamond for each fresh line.

The time occupied in the ruling of a single line may vary from 5 to 10 seconds, according to the length of the line ruled, and degree of accuracy required. The slowest rate named, calls for some check upon the descent of the diamond point at the start of each fresh line. An unchecked fall would speedily ruin the delicate cutting edge of any diamond suited to this work, hence its fall has to be so graduated as to avoid any sort of shock or blow. This is effected through the agency of three plungers and dash cells, the latter containing a fairly thick oil. The plungers are situated at 42 and 42a. The lines are also, by this means, freed from the effects of undulatory vibration of the diamond in a vertical plane.

This brief reference to the action and control of the diamond during the cutting of a series of lines might properly lead to a description of the form of diamond, best suited to this work, at this stage. A careful study of the cutting action of a diamond for ruling lines of such extreme tenuity and perfection as are required for diffraction gratings, is of the very first importance. The amount of work required of a diamond in the cutting of even a medium-sized grating is equal to the cutitng of a single continuous line of over a mile in length. This line, or rather series of lines,

must throughout be without appreciable change in depth, width, or in its capacity to reflect light. These and other considerations, which are particularly well described by Professor Michelson,[1] afford some idea of the amount of care required in the selection, testing and adjustment of a ruling diamond. As it is our intention to refer in detail to the selection, preparation and general manipulation of a diamond suitable for ruling fine lines, and to illustrate its action under varying conditions, further reference is, for the present, postponed.

Driving Mechanism.

This includes chiefly the driving Engine, also such parts of the machine as are essential for the transmission of motion to those of its features just described. Respecting the motive power: while the total energy required may be very small—say below $\frac{1}{8}$ H.P., it must be continuously and uniformly exerted over long periods. Any stoppage, no matter for how short a time, would be ruinous in its effect. Even a slowing down of the engine, such as would cause a variation in speed of more than a few per cent., would be highly detrimental.

It appears to have been the usual practice to select some type of water or electric motor for operating the most recently constructed ruling engines. Electric power seems to have been availed of by Rowland, and also for driving the Blytheswood machine, now at the National Physical Laboratory.

No doubt the electrical drive may be advantageous when suitable storage batteries are exclusively available. As access to such batteries was not at my command it was decided to try the next most suitable driving-power obtainable, viz., a small hot-air Engine. Several preliminary trials with this type of motor were very promising, and as the total energy required was found to be very small, not more than 1-40 H.P., an engine of that nominal capacity proved to be fully adequate for all requirements.

This motor has now been in almost continuous use for about three years and has never once failed. It runs, with a minimum of attention, for comparatively long intervals. And as it gives off but little waste heat, and is free from vibration and noise, it can be placed in a room adjoining that of the ruling engine. It has, in fact, proved an almost ideal engine for accomplishing a somewhat difficult task.

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1 See "Nature." Jan. 11th, 1912.

The method of its adaptation to its work is as follows :—It is set up in an outer room adjacent to the small specially constructed room in which the ruling machine is housed. When at work the engine is regulated to run at about 250 revs. per minute. This speed is reduced to about one-fourth by means of leather bands and aluminium speed reducing pulleys. Motion is given to the machine by a cord passing directly from the reduced drive, through a narrow slot in the wall of the machine house, to the driving wheel (60) on the main shaft (57) of the ruling machine. The shaft (57) is supported on a portion of an underframe which comprises three parts indicated on the plan as B, C and D. It will be noted that plate D rests upon and is bolted to B and C, which in turn are attached, by means of angle brackets, to the lower projecting flange of the machine bed. This construction has the merit of greatly reducing the weight of the whole machine and yet secures sufficient rigidity.

Describing in order the parts of the machine supported on D, B and C; D carries on its upper surface two stout iron pillars, one near each end, which support the driving shaft (57), a circular rod of steel about 28 inches long, resting on bearings (55) with adjustable collars (56). Near its right-hand end are two cam collars (58 and 59). These are constructed so as to slide along the shaft, and are recessed on their inner faces. Within the recess is placed a cam, provided with means for lateral displacement as required; it lies immediately under its lubricating pad and spring (62). A slotted, under cut, circular brass disc (54) is screwed to the opposite end of the main shaft, and provides for the eccentric adjustment of the crank bar head (53). The range, up to three inches, of this adjustment governs the length of the lines. On inspection of Plates VII., VIII. and X. will serve better than further verbal description to make clear the construction and relations of the parts just named.

The second plate, B, carries a single substantial iron pillar (64) which forms the main support and fulcrum of the steel lever bar (61). One end of the lever passes under the cam on 57, and is pivoted at 63, with provision for adjustment and alignment in relation to both cam and ratchet wheel. The ratchet end of the lever is fitted with a small and carefully made frame which supports and controls the pawl or pawls engaging the ratchet teeth (9). The pawls are fitted with the utmost care and are controlled through the agency of the several parts of the frame (66 to 69). Just below the frame carrying the pawls is a support provided with screw

adjustment and lock nut for regulating its height. The top surface of the pillar is hardened and polished, and serves as an arrest for a hardened spherical projection extending from the main lever immediately under the pawls. The arresting pillar and its adjustments are attached to a separate base plate (11) extending out from the base of the main bed of the machine to which it is bolted. The two screws, the heads of which are shown on 11, have no relation to B; they, however, prevent any flexure of 11, due to the weight of the lever and counterpoise (65) descending upon it. It is, of course, important that all movements affecting the ruling be regulated to avoid the sudden arrest of any movement affecting the operation of the diamond point; hence the provision throughout the machine of a variety of parts necessary to its protection. Reference to Plates VII., VIII. and X. will serve to supplement the brief description of the features indicated.

Passing to base plate C. A glance at the plan will show that it is complementary to B in its relation to D and the main bed of the machine, to both of which it is similarly attached. Plate VII. shows its position, and indicates in perspective its purpose. It forms the base of a rigid pillar, of cast iron, supporting a frame which carries the two steel rods (50). These rods, both of which are accurately ground, mainly serve as guides to a small platform of steel, through the agency of which the eccentric swing or throw of the crank rod (52) is converted into a steady, even horizontal "to and fro" motion, as free as possible from any kind of constraint. This movement can be communicated to the ruling carriage as required. The transmission of a smooth and even motion is due primarily to the attachment of the connecting rod (52) to a rotating crosshead placed between the two guides (50) immediately below the lower plate or base of 49; and in part to the carefully fitted sleeves sliding on 50. To the upper surface of platform 48, are secured the various adjustments needed to effect and control the motions of the ruling carriage, the chief of these being the centre block (47), which is rigidly screwed to the surface of 48. The communication rod (44) passes through the centre of 47, one end screwing into a rocking bar on the ruling carriage, the other resting partly in a guide frame (45) and partly in block 47. On opposite sides of the latter (47) are small sleeves or clamps fitted with binding screws; these, if free or clamped at a sufficient distance from 47, will permit 44, on which they travel, to slide freely through 47 without communicating any

motion of the main driving rod (52) to the ruling carriage. When, however, the clamping blocks are brought closer to 47 and secured, the free motion of 44 is restricted to a precise interval, which may vary from 0.01 in. to 0.1 in. or more, as desired; any further motion exceeding the interval to which the setting has been adjusted is of course communicated to the carriage. The purpose served by this preliminary movement of 47, which is not communicated to 44 or the ruling carriage, is to permit of the lowering and raising of the ruling diamond at the beginning or end of each line. This is effected by means of a second rod which passes through 47, and may be clamped therein at any convenient point in relation to the end, which pushed against a small lever. This lever lowers the diamond point before the ruling of a line and raises it from the plate on the return traverse as already explained. The location of this rod is not seen on the plan, as it lies immediately under 44 and parallel with it.

As brief reference has already been made to the operation of the diamond when ruling lines, further allusion to the subject may be deferred until the matter is dealt with in detail.

The foregoing brief outline of the chief mechanical features and operation of the machine and ruling mechanism may fittingly close with a short description of its earliest trial runs, and the subsequent housing, etc., after which a more detailed account of certain of the methods adopted in the construction of its more important parts will be entered upon.

The Housing of the Ruling Engine, etc.

The provision of suitable accommodation for a machine for such exacting requirements as are involved in the ruling of a diffraction grating is of some moment, especially when it is borne in mind that such a machine has to run for long periods ranging from 20 to 200 hours at a stretch. During such intervals there must be no very appreciable change in temperature of the air immediately surrounding the machine, that is, no change exceeding two or three tenths of a degree. Further, during the ruling of a grating the machine must not be subjected to vibrations, such as might arise from the proximity of trains, trams, or any heavy vehicular traffic; nor yet to shocks or tremors due to the operation of other machinery in the same building or immediate neighbourhood. Thus the possibilities to be provided for or against are by no means easily met.

On the completion of the machine, it was not found possible for some considerable time to house and use it under conditions favourable to a satisfactory trial of its capabilities. Hence perforce it remained in an ordinary dwelling-house situated not far from a railway, but otherwise fairly free from serious disturbing influences, other than those inseparable from such a location.

Seeing that for a time no other alternative offered, it was decided to make the best of the available accommodation. The machine was set up on a brick pier, erected below the floor of a small room used as a study, etc., in which the temperature conditions were fairly even. In the main, the results from a series of trials justified the experiment. Certainly, defects of various kinds were apparent, and for some of these remedies were devised, this being one of the objects for which the trial was undertaken. But the principal result of the experiment served to prove that it was possible, in the intervals between the somewhat extreme fluctuations of temperature to which our summer climate is liable, to rule fair gratings, even under adverse conditions.

Subsequently a large sub-basement room, having very thick outer walls, situated under the main Library of the University, and sufficiently remote from disturbing influences akin to those named, was partitioned off into two smaller rooms. One of these is used for spectroscopic examination and work, while within the adjacent room a still smaller room has been constructed especially for the accommodation of the ruling machine. The latter room has double walls, the intervening space being filled with non-conducting material, consequently a very uniform temperature can be maintained for a considerable period, the variations being mainly of a seasonal character. Within this small room, a foundation of dry sand, enclosed within cemented brickwork, has been laid down below the floor level. A heavy stone slab, resting upon the sand, serves to support a brick pier capped with a thick slate bench insulated from the brickwork with rubber pads. The upper surface of the slate is ground smooth and true, and carries the machine and driving gear, other than the engine; the whole being enclosed within a carefully constructed case, consisting mainly of heavy glass sashes, affording ready access to every part of the apparatus. The driving motor is placed outside the machine house, and does not affect its temperature. As the gas consumption of the motor is under one cubic foot per hour, any heat from this source is easily conveyed from the room.

It will be perceived from the foregoing that the provision respecting insulation, isolation, general stability and comparative freedom from temperature variations, combined with easy accessibility, leaves little of importance unprovided for. Naturally, the result of favourable conditions in the housing and surroundings of the machine was a pronounced improvement in the quality of the gratings ruled, even apart from further mechanical improvements resulting from a more extended acquaintance with the working of the machine.

This general account of the more important mechanical features of the Ruling Engine will, it is hoped, convey a fair idea of its structural divergences from other machines designed for ruling gratings; that is, so far as descriptions of such machines have been published. Two such descriptions, more or less complete, have recently appeared, viz., that of the Blytheswood machine, now at the National Physical Laboratory, and a partial account of a new machine designed by Professor Michelson, of the Chicago University. Descriptions of Ruling Engines of earlier design, as for example those of Nobert, Rutherford, and Rowland, have been published. With perhaps the exception of the Blytheswood Engine, few of the descriptions convey to the reader any very detailed or important information concerning the actual construction of a machine of this character. Therefore, as much of the work entailed differs from ordinary instrument work and involves an intimate appreciation of minute values, it may be useful to give some account of the actual work involved in constructing special parts of the machine. The methods adopted were largely due to unavoidable limitations, and better results might have been attained by other means.

This record is primarily the fulfilment of a definite obligation to the University whose generosity has made the building of a machine possible of accomplishment. That the information concerning its construction, which is here given, may be of service to others who may be engaged on similar or related work, affords the possibility of additional usefulness.

In conformity with the foregoing, the following special parts of the machine appear to merit more detailed attention, namely:—

1. *The Screw.*
2. *The Ratchet Wheel.*
3. *The Thrust Plate.*
4. *The Ruling Diamond.*

1.—The Screw.

Embracing :—

1. Cutting the screw thread and (i.) the grinding nut.
2. Process of grinding the screw, including :—
   - (i.) Preliminary separation of Emery or other abrasives.
   - (ii.) Method of Refining crudely separated abrasives.
   - (iii.) Preliminary grinding of the screw by hand.
   - (iv.) Grinding with fine abrasives and semi-automatic control.
   - (v.) Mode of operating the mechanical grinder.
3. Method of testing the screw and its bearings during final correction and adjustment.

I.—*Cutting the Screw Thread.*

The method of cutting the screw thread hereunder described differed but little from that adopted by Rowland and others, but the process of grinding it varied in important particulars. The Rowland screw appears to have been ground between the regular lathe centres by means of a specially constructed brass nut, described in the article on "Screws" in the Encyclopaedia Britannica. The process of grinding followed by the writer varied materially, and is described below. With respect, first, to the operation of cutting the thread.

A suitable bar of mild steel was selected and carefully annealed by slow heating and cooling. Its diameter permitted of the removal of several heavy cuts from end to end of its length, after which it was again annealed, accurately centred in the lathe, and turned down to about $\frac{7}{8}$ in. diameter with repeated light cuts. Later experience with other screws has shown that fine grinding may be preferable to turning as a preparation of the surface for threading, as it is not so likely to warp and compress the rod, and leaves its surface more uniform and true.

The cutting of the thread on the prepared bar differed in no wise from the routine usually followed in the cutting of a good thread. The lathe was run slowly with an abundant supply of potash soap solution continually playing on the threading tool. The advance or forward "feed" of the cutting tool should never result in a heavy cut, and as the work proceeds the cuts should be reduced until those finally taken are approximately only .0005 of an inch. It is, however, important that the last cuts taken should be continuous and even throughout the threaded length of the bar, even though

this should involve a slightly heavier cut than that just named. Also it is material that the over-all threaded length of the bar should exceed by several inches the portion it is proposed to use in the finished screw.

The thread "pitch" and "angle" should be appropriate to the work for which the screw is designed. The pitch value of the screw here described is 20 threads to the inch, a value convenient for subdivision, and the thread angle 50°, permitting of a somewhat deeper thread than the usual Whitworth standard; both "crown" and "root" of the thread, previous to grinding, remained as left from the threading tool. The greatest care was taken so that the intersections of the thread walls with any plane through the axis of the screw should be straight lines—a precaution applying equally to the counterpart threads within the nut. Should the work for which a screw is being cut justify the expenditure of the time involved, it will pay to cut several screws at the outset, selecting two of the best for final grinding.

(i.).—*The grinding nut.*—For grinding his screw, Rowland, according to the Encyclopaedia article, appears to have made use of a brass nut constructed externally so as to taper from the centre towards each end, and split longitudinally into four equal segments which could be fitted to the screw and held in position by means of sliding sleeves or collars adapted to the tapered ends of the nut. The opposing sleeves were connected with bolts and nuts, and could thus be drawn together as the work of grinding proceeded.

Some objection may be taken to the use of this form of nut for grinding a precision screw for the following reasons:—(1) The use of a brass nut upon a steel screw has the disadvantage due to the wide difference in the coefficients of expansion of the two metals, as some heating will take place in the process of grinding. To avoid heating, the work of grinding must either proceed very slowly or else be conducted under water or oil, which entails very serious disadvantages. Hence any gain from the use of brass, due to its superior action with abrasives upon a harder metal, is lost. (2) The division of a grinding nut into four segments appears to be faulty, in that it is possible for one or more sections to move slightly in relation to the others providing, as is almost sure to be the case, there are periodic or other irregularities in the screw. While the method of tightening up the segments is likely to produce uneven pressure, so that one or more sections of the nut may do more than their share of grinding, even though the general trend of the

pressure applied may be in the direction of uniformity of action. Thus any advantage derived from increased surface action, resulting from the use of a segmented nut, may be somewhat discounted by unequal pressure.

The foregoing and one or two minor considerations led up to the decision to employ a continuous steel nut of sufficient thickness and rigidity to resist any variations in pressure which were likely to be used upon it. This nut was cut, bored and threaded up to a length of about 10 inches, which was nearly equal to the length proposed for the finished screw when in use.

This long nut was threaded on the lathe used for cutting the thread of the screw, with a threading tool and such other conditions and precautions as would result in the closest correspondence between the two threads.

The outer wall of the finished nut was slotted through on one side and partly so on its inner opposite side. The two halves of the nut could thus be drawn or rather forced together on the application of moderate external pressure at suitable points. To effect this pressure the nut was encircled with three strong metal rings fitted with set screws bearing directly on its opposite sides. As the rings, under pressure, were slightly elastic or yielding the pressure exerted by them was free from any rigidity likely to lead to seizure between the respective surfaces of nut and screw. Fig. 2, Plate XI. illustrates several of these features.

II.—*Process of Grinding the Screw.*

As may readily be supposed, success in grinding an accurate screw is so intimately related to the abrasive used, that some account of the properties and preparation of those commonly employed is desirable before treating of the method of their application.

The following three well-known substances, in the form of abrasive powders, viz.: Carborundum, Alundum and Emery were used, at least to some extent, experimentally in grinding the screws. As each of these abrasives possesses qualities and structural peculiarities of its own, some explanation of the method of separating or grading, with respect to size and uniformity of grain, is essential to an appreciation of their efficiency.

With respect to their nature and qualities:—

Carborundum, whilst by far the hardest of the three substances, is also the most brittle and the least suited for application to such

a comparatively soft metal as mild steel in its annealed state, as minute particles become imbedded in its surface. Commercially obtainable in the form of very finely divided powders, microscopical examination of even the finest reveals the presence of numerous acutely angular, and frequently needle-like particles, very difficult to separate to a uniform shape and size of grain. Thus, though rapid in action as a cutting and grinding agent, Carborundum is liable to score and scratch finished surfaces to an extent disproportionate to the average grading of the powder used. Moreover, the grades not infrequently contain a considerable amount of graphite, which is apt to soil and obscure the surfaces being operated on.

Alundum, when obtained in the form of an abrasive powder, is usually white and clean. Though not so hard as carborundum, it is tougher and somewhat less variable as to the shape of its particles. It may readily be separated into the finest grades, which are clean to work with and effective in action.

Emery, as an abrasive, is rounder and more uniform of grain than either carborundum or alundum, compared with which it is not so hard as either, but possesses the quality of toughness to a greater degree. Owing to its fairly high specific gravity it can readily be separated into a very effective series of finely divided powders suited for use upon mild steel, on which the finer grades leave a uniformly smooth or even polished surface.

As, practically, the process for the separation of any of these abrasives is the same, we may describe that used for separating emery as typical, the details being as follow:—

(i.).—*The preliminary separation of Emery or other abrasives.*—In connection with other work, considerable quantities of separated abrasives were required; the experience gained in their separation was availed of in the selection and preparation of the materials required for grinding the screws; the process being, in respect to the separation of emery, as follows:—

As commercial flour emery contains a relatively large amount of coarse material, that is of grains over .001 inch in diameter, down to small grains unsuited for abrasive work of the kind here described, the work of separation is best accomplished by first subjecting the crude powder to a preliminary treatment. The quantity dealt with, it must be understood, was proportioned to the work for which this particular separation was required. A third of this amount would, of course, be ample for the supply of material for grinding several screws.

A quantity (usually about 3 lbs.) of the finest flour emery was tied up in a piece of linen or canvas of moderately open texture and kneaded under water, preferably warm, in any convenient vessel until the whole of it had been washed out. This treatment ensures a thorough wetting of all the emery and prevents it from floating upon the surface of the water used in the later stages of its separation. The water and emery were next thoroughly agitated and passed through a fine sieve of wire or milling silk to separate out any coarse grains of emery or other material present. For this and the subsequent operations, four or five large tins holding about four gallons each (empty kerosene or petrol tins do very well) are required. Having washed the whole of the material through a suitable sieve, more water may be poured in to nearly fill up the tin, to which is added a few c.c. of a 20 per cent. solution of Tannic acid, which acts as a deflocculent if not in excess. (Repeated additions of this solution are made with each fresh supply of water as the separation process is continued). After a thorough stirring, allow the vessel to stand for ten minutes and then decant with care the upper three-fourths of the water, carrying in suspension the finer emery, into another tin. This process should be repeated several times, with fresh supplies of water, until it is seen that most of the finer material has been decanted from the original sample. The sediment remaining will consist mainly of the coarsest grains present in the original samples, and may be set aside to settle in a smaller vessel or beaker and afterwards dried off. We have next to deal with some 8 or 10 gallons or more of water, containing finer emery than will fall through the depth of water each vessel contains—say 8 to 10 inches in 10 minutes; but will settle in say 20 minutes. Hence we proceed with the separation of this finer material much in the same way as we dealt with that which came down in 10 minutes, providing sufficient vessels are available; if not, allow the vessels containing it to stand and settle for about 80 minutes, when the upper portion of the water in each, in which there will remain in suspension only fine material of little or no abrasive value upon a screw, may be poured away as close to, but without disturbing the sediment, as possible. The several sediments having been transferred to one vessel, with additional water as required, and well stirred, are allowed to stand for 20 minutes, when the upper portion of the water containing still finer emery is poured off, as before, into other tins. The addition of fresh supplies of water and time for settlement (20 minutes) being continued,

so as to secure as much of the fine material as possible. The sediment remaining, consisting mainly of material which settles in 20 minutes, may be put aside for use or further treatment. We may next deal in the same way with the still finer emery contained in the water decanted off from the 20 minutes sediment. Much of this will require a still longer time—say 40 minutes—in which to settle and so obtain a further and yet finer grade of emery. The addition of more water and decantation, etc., being continued, as in previous grades, the time interval only being extended to 40 minutes with a corresponding increase in care in the several operations. In order to obtain a small supply of the finest effective material present, it will be necessary to carry on the separation process with a 60-minute interval for settlement, the sediment from which will be small in bulk but proportionately valuable for the final abrasive work.

The process of separating abrasives thus outlined is both slow and tedious, and may extend over one or two days. As, however, reliable separations are absolutely necessary if good results are desired, it pays to go to considerable trouble to obtain them.

It is, of course, not necessary for the purpose of grinding one or two screws only to undertake the separation of so large a quantity of material as that above named; but it is essential that an effectual grading of whatever abrasive it is proposed to use be made; and also that the process of separation should be carried to an even greater degree of refinement than is possible with the rough and ready method above outlined. This process only afforded a series of crude powders in which there is considerable variation in the size of the grains.

To secure greater uniformity of grain, and greater smoothness in working, than is possible with any of the four sediments or separations just described, the following more exact method of treatment was adopted :—

(ii.).—*Method of Refining crudely separated abrasives.*—Before commencing to grind the screws, we had the good fortune to have at hand a series of carefully separated powders of all the abrasives we have described and used; also some knowledge of their behaviour under varying conditions upon a variety of materials. This experience had, in the main, tended to show that the greater the care bestowed upon the separation of an abrasive, the more efficiently and as a rule more quickly, could a desired result be obtained.

Guided by this knowledge, confirmed by microscopical evidence from the examination of a variety of powders, it was decided to carry on the process of separation of the three finest grades of emery, obtained by the decantation method of separation, to a greater degree of refinement, the method adopted being essentially as follows:—

A circular upright glass jar, about 10 inches high by 5 inches wide, was roughly graduated into one-inch spaces. With this jar, the syphon and attachments shown in Fig. 1, Plate XI., were used. The attachments include a glass tube of about 5 m/m. bore, bent as indicated; the short arm being longer than the depth of the vessel used with it. The longer arm is extended as required with rubber tubing; it must be more than twice the length of the short arm, and retained at a length convenient so as to maintain a constant pressure at the outflow. Various sized jets to control the overflow of the syphon are required. A convenient series of these jets, which are not difficult to make and adjust, should permit of the whole of the water being withdrawn from the container during intervals of about 10, 20, 40 and 60 minutes.

It should be noted that the short arm of the syphon passes through a large circular piece of cork, which acts as a float upon the surface of the water in the graduated container, and also serves to regulate the depth of the intake tube. The bent syphon and its attachments are suspended and counterpoised by means of a cord, pulleys and weight, as shown in the figure, the outfit being completed with overflow receptacles.[1]

Before using this outfit with the particular grade of abrasive it is proposed to refine, the rate of flow from the syphon should first be adjusted. If the required grade is one of 20 minutes, the water level in the container should be lowered one inch in two minutes. Generally it is better that the time should exceed rather than fall short of the interval for which the adjustment is made. Everything being in readiness, the container is filled to the upper graduation mark with thoroughly mixed emery and water and allowed to settle for about 2½ minutes, before the float is lowered upon its surface or the syphon clamp removed. On releasing the latter the water level should fall to within about one inch from the bottom of the container. The inlet tube is prevented from descending too near the surface of any sediment on the bottom of the container by inserting 3 pins or bits of wire tripod-wise into the under surface of the float

1 The overflow vessel must be placed well below the syphon outlet and not as shown in the figure, which was thus drawn for convenience of reduction.

so as to project below the inlet at least one inch. This device will prevent the withdrawal of any coarse sediment from the bottom of the container in case the clamp should not have been replaced in time. After syphoning off to a safe level the clamp is replaced, the tube and float withdrawn and a further supply of untreated sediment and water poured into the container and the syphoning conducted as before, afterwards water only is added and the syphoning continued so long as any considerable proportion of abrasive remains in suspension. The water withdrawn through the syphon carries with it most of the fine material suspended in the container; the bulk of the heavier particles, maintaining their initial advantage in descent during the stated interval, make their way to the bottom of the vessel. By this method of treatment, as will readily be perceived, a much larger proportion of fine material can be withdrawn in a given time, while the regulated discharge ensures a more uniform grading.

Respecting the fine material thus withdrawn, the vessels containing it may be left to settle until the water appears comparatively clear, when it may be poured off and the sediment transferred to an evaporating dish preparatory to drying off. Before drying, the material should be examined under a microscope and the average size of the grains determined, in case it should be neecssary to repeat the separation process, with a slightly longer time interval, in the event of too great a disparity between the size of the various grains.

Much the same mode of procedure as the foregoing applies to each of the crude separations first made, with correspondingly coarser or finer jets and longer or shorter periods for settlement. It must be borne in mind in this connection, that a small quantity of carefully separated abrasive is far more effective and uniform in its action than many times the same quantity imperfectly treated. Hence, though the process of separation may appear tedious, it will prove to be a wise economy to carry it through. Four grades only of any particular abrasive thus treated are all that are really necessary to complete the grinding of a precision screw, providing the thread has already been carefully cut. With a view to present to the reader a graphic representation of the uniformity in size of grain attainable by this mode of separation, a series of photo-micrographs with a magnification of approximately 75 diameters has been prepared and are shown as Plate XII., Figs. 1 to 6. Respecting these photographs it is first necessary

to point out that it is extremely difficult to secure uniformity in the distribution of powders so fine in grain as those represented owing to their tendency to clot or segregate; and also that the magnification used was somewhat too high for the coarse-grained samples, and too low for the finer ones. In spite of these drawbacks, the photographs render sufficiently apparent the differences in size and character of the grains. For example, Figs. 1 and 2, Plate XII., illustrating alundum, the grains of which are respectively .0015 in. and .0003 of an inch, are adequate to make clear the difference in grain between the respective sizes. Again, Figs. 3 and 4, representing two examples of carborundum, show clearly the more angular character of the grains as contrasted with alundum, and a coarse emery. The difference between carborundum and emery, with the same sized grain, is less striking but yet appreciable; the emery being the more uniform of the two samples.

Fig. 5, Pl. XII., shows an emery with an average grain of .001 in. diam., the coarsest abrasive used upon the screw, and with the rounded character of grain already referred to. The fine emery shown as Fig. 6 was used mainly for finishing purposes only. acting rather as a polishing agent than as an abrasive, and leaving the screw threads in a semi-polished condition.

Combinations of emery, alundum and carborundum, having the same size of grain, were occasionally used, and proved advantageous in the earlier stages of the grinding process.

Having prepared a series of abrasives, the operation of grinding the screws was entered upon, and may for convenience be divided into two stages, the first of these being the *preliminary rough grinding by hand*, using a relatively coarse abrasive, and the second stage, grinding with fine abrasives and more or less *complete automatic* or *mechanical control.*

(iii.).—*The Preliminary grinding of the screw by hand.*—This operation involved fitting up the lathe with extra long centres so as to permit the grinding nut to travel beyond the threaded part of the screw bars for at least several inches at each end. For this purpose, the screw was revolved slowly, while the nut was held and controlled by hand. The whole of the grinding at this stage was done with one grade of emery only, viz., that described at Fig. 5, Pl. XII., having an average grain diameter of .001 inch. This emery, mixed with oil, was fed into the nut along the slot, the ring clamps being released to permit of its introduction and even distribution. Pressure upon the nut was applied very gradually

at this stage, and the grinding continued for ten minutes, when the nut was reversed and a fresh supply of emery fed in. Thus the work of grinding went on under moderate pressure, regular reversal of the screw and fresh supplies of emery and oil.

As already mentioned, two screws were ground with the same nut, which necessitated a change from one to the other about every half-hour. No very great precautions were taken to maintain uniformity of temperature during these early operations, nor did this appear to be necessary, seeing that each grinding operation lasted only for a comparatively short time. The grinding, as described above, covered about 12 hours' actual work, which was distributed over several days. During this preliminary grinding, attention was mainly given to the supply of abrasive and oil, which was carefully and uniformly distributed over the full length of both screw and grinding nut at frequent intervals, the precaution being taken not to exhaust its action before renewal. Care was taken to apply only moderate and uniform pressure upon the nut, which was regularly reversed and changed with respect to the screw, and supported so as to avoid flexure. The precaution to wash out the nut with kerosene, and clean off the screw with cotton waste about every three hours, was not overlooked.

When inspection with a magnifying lens indicated that the whole of the threads appeared to have been ground to a uniform condition, as shown by the disappearance of any tool markings, it became necessary to devise some simple form of test, capable of revealing any very marked periodicity, and general condition of the screw throughout its entire length as regards the crowns, roots and angles of the threads and their bearing surfaces. For the rapid inspection of the screw with respect to these features, a small examination bench was constructed as follows:—A platform of thick plate glass, rather longer than the screws and three inches wide, was supported at each end, at a height of about three inches above a wooden base. Screwed to this base were two guides, also of wood, adjusted so as to permit the square base of a microscope stand to slide between them from end to end of the platform. During an examination the screws rested upon the glass platform with the threads interlocked and adjusted parallel to the travel of the microscope along the main base. With the aid of a long strip of white card, placed below the platform supporting the screws and adjusted to an angle suited to the direction of the incident light, ample illumination for a magnification of 20 diameters or more

was obtained. The two screws rested upon supports slightly inclined to each other, hence they could be revolved, reversed, interlocked, or interchanged without disturbing their adjustment in relation to the travelling microscope. This comparatively simple and easily constructed bit of apparatus proved quite satisfactory for examining the condition of the two screws, not only during the preliminary grinding stage, but up to the final mounting of one of them in the completed engine, it was only superseded, after a number of gratings had been ruled, by a more rigorous method of testing described on a later page.

(iv.).—*Grinding with fine abrasives and semi-automatic control.* —A thorough examination of the two screws under the microscope, with the aid of the apparatus above described, tended to show that it was not desirable to continue grinding without appliances which would permit of a more precise control of the operations involved. Hence the following method for attaining variable speed control, freedom from stress, other than that due to a uniform tortional resistance, and the maintenance of a more uniform temperature, was adopted. An attempt to eliminate temperature changes resulting from friction by means of a stream of running water or oil, surrounding nut and screw, proved unsatisfactory and was abandoned at an early stage in favour of a reduction of speed and pressure. An inspection of Fig. 2, Plate XI., will make clear the following brief description of the appartus used. Fig. 2 is a photograph of the complete mechanism used at this stage, and in all subsequent grinding operations. It comprised a strong wooden platform or plank securely bracketed to the wall of the workshop in a position conveniently near the overhead driving gear of the lathe which furnished the operating power. A strong flanged accurately bored metal socket about 6 in. long was screwed to the upper surface of the platform. Through this a mandril passed, carrying on its upper end interchangeable driving wheels, and on its opposite end below the platform a small chuck fitted with universal movement. This chuck supports a steel rod about 15 in. long, to the lower end of which the screw is attached, the latter being thus provided with a free conical pendular motion of about 20° amplitude; two jockey pulleys for transposing the vertical travel of the driving band, and a reversing lever (not shown) complete the driving mechanism. In Fig. 2, Pl. XI. the screw and nut are seen in position, exactly as in the operation of grinding. The details of the nut include its two surrounding rings and clamping screws, previously described; also

a centrally situated steel ring carrying reversible suspension hooks and two projecting arms which bear against polished steel rods extending from platform to floor, and serving as guides to direct and steady the nut in its ascent or descent, and also prevent its rotation. As will be seen, the grinding nut is counterpoised by weights; the pulleys and cords travelling with a minimum of friction.. The rotary motion of the screw was made variable, ranging from 120 down to 40 revolutions per minute, the latter being the slowest rate of speed used. It is hardly necessary to state the fitting up of these simple appliances was carried out with care, the rotation of the spindle, particularly, being made as true as possible, and free from vibration or shock, especially at the moment of reversal, which was always made with a reduction in speed.

(v.).—*Mode of operating the Mechanical Grinder.*—In operation, the mechanical device just described presented no great difficulty. Once the screw had been adjusted to run smoothly, the nut was screwed into position, the clamps meanwhile being released, and oil, without any abrasive, applied as a lubricant, and the machine was ready for a trial run. In order to avoid the possibility of seizure between screw and nut, the latter was controlled by hand for a time, the projecting sleeves being withdrawn from the central ring, leaving the screw free to revolve while the machine was being stopped. These precautions were no longer necessary once the machine was found to run smoothly, and some experience of its working had been gained. It will be understood that grinding with a power-driven machine differs materially from the same work controlled by hand, and is to a greater extent dependent upon the sense of touch and hearing; these being the chief means of estimating and controlling the nature and extent of the work being done.

The mode of applying abrasive is now of considerable importance, and can be controlled and varied so as to materially modify its effect upon the screw. Ordinarily, when applying a fresh grade of abrasive or re-commencing operations after cleaning nut and screw, it was usual to release all clamping pressure and run off the nut below the screw; the latter was then coated with a thin even film or layer of abrasive mixed with oil—and in this connection it may be remarked that a light mineral oil and olive oil, in equal parts, was later used. This combination was found to possess certain advantages over either of its components used alone. Thin mineral oil was found to dry up rather rapidly and was more liable to produce an increase of temperature in consequence, while olive

oil alone proved somewhat too viscous, especially with the finer abrasives.

The screw having been evenly coated with abrasive, the nut is run into a central position upon it, and pressure brought to bear, evenly and slowly, rotating the nut by hand while this is being done. In order to ensure a positive and uniform pressure the clamping screws are advanced alternately until they are felt to grip gently, and are then slightly relaxed. We thus ensure a condition for both nut and screw in which it will be safe to run for a short time. During all starting operations, close attention is paid to the machine, until we are assured the running is satisfactory. Providing the pressure on both rings is properly proportioned, and the condition of the screw is known to be of a fairly uniform character, it is quite safe to run at a speed of 120 revolutions per minute, with an abrasive (alundum) of a uniform average diameter of grain of about .0007 inch. This was found to be a suitable grade to follow that of emery used in the hand grinding already described. A mixture of equal parts of alundum and carborundum was, however, later substituted for alundum alone. Having allowed the nut to travel up and down the screw a few times, the former was run off and reversed, and re-engaged by hand over several threads; the latter being a precautionary measure *never omitted*, otherwise damage might result to either nut or screw or both. The nut having attained a central position once more, some readjustment of pressure may be required. This is effected exactly as before, and when found uniform, the work of grinding should proceed for the same time interval as before reversal. After the lapse of this interval, it will probably be found that the abrasive and oil tend to work away from the centre to opposite ends of both screw nut, and if attention were not given to correct this tendency, it would eventually lead to a slight tapering of the screw from its centre towards each end, and particularly to that end which was lowest during grinding. At a later stage, it was found possible to counteract this tendency, partly by varying the distribution of the abrasive, and partly by extending or restricting, as the case required, the travel of the nut upon the screw. It might readily be supposed that the central portion of the screw would be more rapidly ground than the ends, providing the nut does not travel over the full length of the screw after each reversal—to permit which is not usual or wise. As a rule it was found best to reverse the motion of the nut when from two-thirds to three-fourths of the screw

length had been traversed, i.e., about one-third of the nut should generally remain engaged upon the screw.

Regarding the re-distribution of the abrasive as the grinding proceeded; this was usually done by using a flat camel's hair lacquering brush to collect any excess oil and abrasive and transfer it back to the central and upper portion of the screw, in advance of the travelling nut in either direction; whilst additional supplies of oil and abrasive were carefully inserted into the slotted nut by means of a piece of leather cemented to a strip of aluminium or zinc. This proved both safe and satisfactory, as only the edge of the leather, charged with abrasive, came into contact with the revolving threads. After about three hours of carefully controlled work, it was customary to run the nut off the screw, detach it and thoroughly wash out the threads with kerosene, with the aid of a stiff tube brush. The screw also would be dismounted and similarly treated. In this, and all other operations involving reversal or detachment of the nut, attention was constantly required to avoid the accidental introduction of dust, hairs, or any kind of fibrous material, which might cause the nut to jamb or seize. Attention was also directed to any temperature change by inserting a sensitive thermometer into the nut whenever the latter was detached; three degrees being the limit of variation at this stage of the work. After cleaning the nut and screw, it was usual to make a fresh examination of the latter under the microscope; its condition, in respect to the action of the abrasive upon it, being noted. At the same time the diameter of the screw was measured with a micrometer; the measurements obtained providing data for adjusting the travel of the nut upon it, and to some extent, for any increase or decrease in pressure; though, as a rule, the latter was more accurately controlled, during the operation of grinding, by the sense of touch. No precise record of the time taken to reduce the surface of the threads to a uniformly smooth condition was made at this stage, but for this particular grade of abrasive, it was not less than 40 hours; the work being distributed over a fortnight or more. Inspection then showed a decided improvement in the condition and appearance of the screws. The scoring due to the coarser emery had practically disappeared; at the same time the form of the thread had been well maintained, and the gauging was uniform and good. It was therefore decided to proceed with the next finer grade of abrasive, viz., .0005 inch alundum and carborundum in equal parts; the grinding operations and other procedure being

exactly similar to those of the preceding grade. It was noticed, almost at once, that this somewhat finer abrasive had a different grinding sound, and somewhat smoother action, appreciable to the touch when the nut levers were held by hand for a short time. A longer time was given to grinding with this particular grade, the work extending over the greater part of a month. The improvement effected could then be easily appreciated in the smoother movement of the nut, apart from that seen under the microscope, which was satisfactory throughout the full length of the screw. It was therefore decided to use one of the finest grades of emery and carry on the grinding with this to a finish. This work occupied another week or more, and proceeded satisfactorily, although the effect upon the screw was less pronounced than might have been expected.

As it now appeared that little further improvement could be effected by grinding, both nut and screw were carefully cleaned, and the latter slightly polished with the harder residueo of washed rouge, that is the purplish portion, which imparted a slight gloss only to the finished work.

The screw having been freed from all traces of polishing material, the nut was traversed to and fro upon it, with a trace of oil only, and pressure just sufficient to ensure the closest approximation to contact with the screw which could be obtained without risk. As this procedure gave no indication of inequalities of pitch or diameter, and direct microscopical examination and comparison by the methods described was equally satisfactory, it was decided to mount the screw in its permanent position upon the bed of the machine, and submit it to the test of an acutal ruling or series of rulings, in order to determine under working conditions its accuracy and other behaviour. Preparatory to this step, it was necessary to cut away a portion of the threads from each end of the screw, to provide space for bearings and the ratchet head. To effect this, the original centres of the screw bar were availed of for the preliminary turning down to obtain a first approximation to the limits of accuracy required. As the original axis of the bar and that of the ground thread were probably no longer coincident or parallel, and as it was of the first importance that the thread axis and bearings should be strictly in alignment to ensure this condition, the grinding nut was first mounted upon the lathe carriage, so as to travel approximately parallel with the ways of the bed: the screw was then threaded through the closely fitting nut. The bearing portion of each end of the screw was next slowly revolved

and advanced past a small fine carborundum grinding wheel, running on the dead centres of the lathe, at about 5000 revs. per minute. This plan of "truing" the bearings ensured a very close agreement between the thread and bearing axes.[1] The two bearings thus ground were then available for correcting the centre holes on which the threads were first cut, so that eventually, centres, bearings and threads were found to be in such close agreement that the usual mechanical tests applied to them indicated no appreciable error.

As we are not here concerned with the work intermediate between what has just been described, and certain further corrections made at a later period, and which resulted in the practical elimination of all measurable irregularities between screw, nut and bearings, we may at once proceed to describe how this further improvement was accomplished.

III.—*Final method of adjusting and testing the screw and its bearings.*

It has already been stated that the ruling machine was completed up to a certain stage, and a number of trial ruling made under unavoidably adverse conditions. As was anticipated, the results from these early trials were imperfect but valuable in that they served to bring under notice defects of various kinds. Among these one was such as could have been caused either by a bent screw or by a screw whose axis was eccentric with its bearings by amounts too small for the rough method already described to detect.

After some experiments had been made, the following device for the detection of small errors in the screw or its bearings was designed and constructed, and proved both convenient and effective. An inspection of Fig. 2, Plate XIV., which is a plan of the apparatus, will aid the verbal description here given.

As a sufficiently sensitive test could not be directly applied to the screw when in position upon the ruling machine, both screw and nut were detached and placed in polished steel V-shaped bearings, secured to the carefully worked surface of a heavy slab or surface plate of glass about $1\frac{1}{2}$ inches thick. The strict alignment of the V bearings with respect to each other was obtained by first placing upon them a straight round bar of steel accurtely ground to the same diameter as the bearing surface upon the screw. The use of this bar ensured the parallelism of the V block surfaces.

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1 This method of correcting the bearings assumes the straightness of the screw; an assumption which afterwards was found to be incorrect.

The glass slab carried, in addition to the screw and its bearings, a long rectangular bar—also of glass—lying parallel to the screw, and serving as a guide and support for the extension lever bar of the nut, in a position identical with that occupied by the same parts upon the ruling machine when in action. Hence the nut could be traversed from end to end of the screw, without the slightest movement in rotation. A second long rectangular bar—In this case of machined iron lying parallel to the screw, but about 6 inches from it, was also secured to the base plate. This iron bar served mainly as a guide for a smaller bar or block of iron supporting a small travelling microscope which could be moved in a direct line from end to end of the screw. The microscope was fitted with an objective and eye-piece, affording a combined magnification of about 25 diameters; the eye-piece being fitted with a micrometer scale having 100 scale divisions within the field of view. The V bearings supporting the screw were both exactly of the same dimensions and height, and one of them was provided with a thrust plate enabling the screw to be rotated without end play. For convenience in rotation, and recording of positions, the other end of the screw was fitted with a simple graduated disc and short lever handle.

The swivelling steel ring surrounding the nut carried a carefully made parallel plate of quartz about $1\frac{1}{2}$ in. long by $\frac{5}{8}$ in. in width, and thick enough to prevent flexure. One face of this plate was cemented to the steel ring in a horizontal position, while its outer face, which was optically true and polished, could be brought to a position strictly in alignment with the travel of the nut, and therefore of the screw axis, an essential condition for this method of testing.

This agreement was arrived at by trial and error, the quartz plate being adjusted so that a longitudinal movement without rotation of the screw in the V bearings caused no change in the position of the indicator (described below) as seen in the microscope.

To complete the testing equipment, a delicately sensitive lever indicator was constructed. This was provided with adjustable bearings and a needle index bar with a magnification ratio of about 1 to 20, with respect to its length and fulcrum adjustment; or with the microscope a combined magnification of 500 diameters. The index point of the needle moved in a vertical plane across the scale of the miscroscope eye-piece, and was adjusted, when in use, to

indicate a movement of rather less than one micron per division of the micrometer scale and values of less than half that amount, or 1/50000 inch were both appreciable and reliable. In operation the lower bearing point of the indicator—a polished steel sphere—was brought into contact with the face of the polished quartz plate just mentioned, the indicator needles being inclined at about 45°; an angle both correct and convenient for the position of the microscope reading scale, and other predetermined constants of the apparatus. These various adjustments called for the expenditure of some little time and care at the outset, but any difficulties were soon mastered and the instrument proved reliable and effective throughout its subsequent use.

As soon as the foregoing method afforded the necessary assurance of reliability, a series of tests were made and the readings carefully tabulated, the results being recorded in graphic form. One of the graphs, the earliest obtained, has been reproduced as Fig. 1, Plate XIII., and will serve to illustrate the actual condition of the screw at this time, before any attempt had been made to correct the errors revealed by this method of testing. Seeing some explanation is necessary to make clear the interpretation of the results obtained from the measurements and graphically recorded as Figs. 1, 2, Plates XIII., and Fig. 1, Plates XIV., we may first indicate the procedure followed in obtaining the data for constructing the graphs here presented.

The curve in the upper part of the figure was based upon a record of some 16 readings (see below) taken at half-inch or 10-thread intervals over the full length of the screw in the following manner. The three-inch nut was first carefully fitted to the screw and run into position, back towards the thrust end of the screw up to the limit of the threads available, all the threads of the nut being engaged. With the spherical end of the indicator in contact with the quartz plate, the screw was slowly revolved through a complete turn, the observer meanwhile noting any change of index point, in relation to the scale in the field of the microscope. It is here worth drawing attention to the fact that the maximum and minimum readings always corresponded with the same points on the divided circle used for locating these positions, indicating that the bend upon the screw was of the nature of a *plane* curve.

A record of the mean deviation of the index per revolution for three revolutions, was usually made for each position. This was done for every half-inch interval over the range of threads available

for measurement. The set of readings here given was obtained before any further work was done on the screw by way of correction.

Distance from zero position.		Microscope deflection.	Distance from zero position.		Microscope deflection.
0″	-	30.5	4.0″	-	44.5
0.5	-	32.5	4.5	-	44.5
1.0	-	33.5	5.0	-	43.0
1.5	-	35.5	5.5	-	43.0
2.0	-	40.0	6.0	-	41.5
2.5	-	40.5	6.5	-	39.5
3.0	-	43.0	7.0	-	37.5
3.5	-	43.0	7.5	-	37.0

The method employed in plotting these observations was as follows :—

In the figure (1, Pl. XIII.), the abscissae along the line O X represents the distance of the centre of the nut from its position at the first observation where the abscissa $=0$; measuring the first reading or its reduced value from O and the last reading (that at $7\frac{1}{2}$ in.) from X both downwards we obtain the points A and B respectively. Then using the straight line A B as base line, all the intermediate readings were plotted by measuring them upwards from A B. Thus we obtain the curve O M X which represents graphically the shape of the screw between the points where the nut was situated at the first and last readings. Thus at the point on the screw represented by M, the interval N M represents the sum of the errors of bend and eccentricity, M P representing the ordinate at M of the curve formed by the screw, and P N the amount by which the screw is "drunk" at M due to bearing eccentricity; the actual amount of error in each case being given by the scale on the diagram.

With respect to the value of the microscope readings mentioned above. One division of the microscope scale was actually .00009 cm. but for convenience the observed readings, which obviously were twice the actual error, were plotted in each case. The inch values given as a scale to the diagrams are approximate only and represent the errors, not twice the errors.

Regrinding the Screw.

Progress and results at intervals of from 3 to 5 hours.—The series of curves shown in Fig. 2. Pl. XIII., have been prepared in order to illustrate the improving shapes of the screw as re-grinding

proceeded. The base or reference line A B of Fig. 1 has, however, been omitted in Fig. 2 for convenience. In all the tests the values of the negative ordinates O A and X B remained the same, within the limits of experimental error, as in the case of the first test (Fig. 1).

With respect to Fig. 2, the first of the four curves is that already described Fig. 1, included for direct comparison. The second curve shows the result of 15 hours' work, and is the fourth recorded during this period. It clearly shows the reduction of the original error to about one-half. The third curve was drawn after a further period of grinding, with the same abrasive and for about the same time as before, and with the same proportion of improvement. Afterwards the grade of[1] abrasive was reduced to .0003 in.—emery in this case—and the grinding continued at a slow rate for some hours longer. Finally, the result shown in curve 4 was obtained and was deemed satisfactory.

It now remained to correct the eccentricity of the bearings. To effect this no better plan than the one previously tried could be devised; it was therefore followed, and as the screw was now straight, with entirely satisfactory results, as may be seen in Fig. 1, Pl. XIV. Here the curve O X and base line A B were plotted exactly as in Fig. 1, Pl. XIII., and it will be seen that the negative ordinates O A and X B which represent eccentricity, have been reduced to about .00002 in. and .00003 in. respectively, a condition which it would be difficult to improve with any certainty of success. The results from these two improvements, combined with minor adjustments, have been evident throughout all subsequent ruling.

2.—The Ratchet Head.

The construction of the Ratchet head or wheel differed in some respects from similar parts of other ruling engines. These parts, so far as they have been described, have usually been made of brass or gun metal throughout; probably for ease and convenience in cutting the teeth.

It was decided in this case not to follow the usual practice, but to construct a composite head of gun metal and steel; the hub, with a flange for supporting the steel rim, alone being gun metal. As the general design and construction of the head are well shown from various view points throughout the series of plates illustrating the

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1 Alundum, grade ·0005″ had been used up to this stage.

machine, it is not proposed to enter upon a detailed description, but merely to specify the principal dimensions and essential features. The central hub and the flange for supporting the steel rim were turned from a single casting of hard gun metal; the hub being about $1\frac{1}{2}$ in. through and made to fit the corresponding tapered bearing upon the screw. The flange of the hub was about 8 inches in diameter and formed the bed and support of the circular steel rim. The over-all diameter of the rim was 10 inches and its finished thickness just under $\frac{1}{4}$ inch. This steel rim, which was turned, annealed and afterwards ground and lapped with great care, was accurately fitted and bolted to its gun metal support without avoidable stress of any sort, and with only just sufficient freedom to accommodate for any differenec in expansion.

Two similar heads were thus constructed; in one 360 and in the other 540 teeth, were eventually cut. The cutting of these teeth with the necessary accuracy was a formidable undertaking, and occupied a long time. As no milling machine possessing even approximately the accuracy required for cutting the teeth was available. it was decided to grind them out, a method which, although slow and laborious, promised to afford accuracy of a fairly high order. The first requisite for the method proposed to be followed was a well divided circle. Therefore, with a view to securing one sufficiently correct, a number of theodolite and other circles were examined and tested as to their correctnes; but all failed in this respect. Hence it was decided to have a circle constructed and specially graduated. Messrs. Watts and Son, of London, who had recently built a very accurate circular dividing engine, were communicated with, and they undertook the work of making and graduating a suitable disc of silver. On this circle each of the 360° was divided into 10 minute intervals with graduation lines sufficiently fine to bear a magnification of 100 diameters. The completed circle fully met expectations, its accuracy being well within the limits stipulated for, viz., $\pm$ 2.5 seconds. Indeed, after a series of tests we found its accuracy comparable with that of a circle ruled by the same engine under approximately the same conditions and tested by the Imperial Institute, Charlottenberg. The maximum error of any sort found in the latter were $+1.4$ seconds and -1.7 seconds.

The provision to be made for the actual operation of grinding the teeth was next considered and was mainly worked out as follows:—A number of specially thin dental wheels, 3 inches in

diameter and made of the very hard greenish variety of carborundum, were obtained. Each wheel was mounted upon its own steel spindle, from which it was not again removed, and with the aid of suitable diamond tools its periphery was trued and cut to the shape necessary to reproduce by grinding the form of teeth required. The wheel spindles were adapted to run in a lathe cutter frame with hardened centres, with overhead drive and provision for speeds up to 6,000 revs. per minute as free as possible from vibration. A series of wheels were thus fitted varying in grade of grain, but all relatively fine and made up with a vitreous bond. The coarsest of these wheels were used as originally made for the first roughing cuts in which extreme accuracy was not called for. But the carefully formed edges of the finer grade wheels, used for finishing the teeth, in which process both great accuracy and high-finish were required, were charged with diamond powder obtained by crushing and grading after the method described for preparing other fine abrasives. This grading was of course done on a proportionately small scale and with the aid of petrol in place of water. Several grinding discs were so charged, each with its own grade of diamond in the following way:—

The spindles, carrying each its own wheel finally trued and turned to the correct shape, were supported on centres in a small frame convenient to a tiny blow-pipe flame arranged to impinge upon the edge of the disc and parallel with its face. The disc or wheel, carefully freed from grease or dirt of any sort, is then slowly revolved and its edge moistened with a strong solution of soda carbonate, using a fine camel-hair brush and working with the aid of a magnifier, which is necessary as the dimensions of the trued edge of the disc are very small. The application of the alkaline solution ensures the even distribution and adhesion of a film or layer of a thin cream (made up with water) of glass enamel composed of extremely fine ground moderately hard glass, containing about one part in three of diamond powder of the particular grade suited to the work to be done. The liquid enamel thus prepared, fills up the pits and crannies in the edge of the disc, which are of course very small in the case of a fine grade wheel. As soon as the layer of enamel is dry, that is in a few minutes, it is ready for firing. To effect this the wheel and spindle are first slowly and uniformly heated with a bunsen flame, after which the blow-pipe jet is brought into position to play quietly upon the extreme edge of the disc, which is quickly brought to a white heat, fusing the painted

on enamel (which binds the diamond dust) to a thin vitreous coating on the edge of the wheel. The fusing process requires care, skill and judgment. The wheel during the process is slowly revolved and kept under observation with a magnifier. More than one coating of enamel will usually be required to ensure an enduring result. It will be understood that this treatment does not injure or fuse the diamond fragments, which, if small and uniformly graded, remain securely embedded in the enamel, filling the minute cavities of the wheel edge. As the thin outer skin of the enamel wears away when the wheel is in operation the diamond particles are exposed; hence after a little preliminary use, the wheel edge when used for cutting or grinding purposes which require prolonged endurance and permanence of shape, becomes the equivalent of a diamond wheel. It is, however, important that during is use, either upon hard steel, glass, or any similar substance, the precaution not to overfeed or force the rate of cutting be strictly observed. With due attention to these precautions the "life" of the cutting edge of the wheel may be greatly prolonged. The art of using such a wheel correctly and effectively can only be gained by experience.

The method of mounting and moving the ratchet head had next to be provided for. The arrangements made for this purpose, also for supporting and revolving the graduated circle and for maintaining in a rigid position the two reading microscopes used upon the circle, are sufficiently illustrated in the photograph, Pl. XV. This photograph, if carefully examined, is self explanatory in respect to almost every detail. Some of the principal features shown therein, apart from the lathe and its fittings, are, first, the steel rod forming the spindle on which are mounted from left to right in order—the ratchet wheel, next to this the tangent-wheel and its fittings for moving and clamping the whole system during work upon the ratchet. Finally the Watts divided circle for spacing and controlling all angular movements upon the ratchet. The ratchet wheel and divided circle were most carefully centred and correctly related to each other by grinding the spindle on "dead" centres and making full use of the two microscopes in the adjustment of the reading circles. Once these adjustments were effected the ratchet and divided circle were never displaced relatively to each other during subsequent grinding operations upon the teeth. The microscopes were securely mounted upon the thrust bar or socket of the back centre which also provided for rotary swing and rough focussing adjustment. Fine adjustments of the microscopes were effected

by means of the sleeves carrying the tubes; provision was also made for a certain amount of lateral displacement. The optical equipment of the microscopes afforded a magnification range of from 50 to 100 diameters which was found to be ample for all purposes. The steel spindle, carrying the whole system, was supported on the two "dead" centres of the lathe, which were secured in a "locked" position. The cutter frame, supporting the grinding disc and guide pulleys, is seen in a working position immediately in front of the ratchet wheel. During the operation of cutting the teeth the main carriage or saddle of the lathe bed, in the tool holder of which the cutter frame was clamped, was traversed along the ways of the lathe for the short distance, usually less than an inch, required to complete the cut and clear the ratchet. To effect and control this movement, the apron mechanism of the lathe carriage was made use of and proved to be both steady and reliable.

During work upon the ratchet, and particularly near its final stage, provision was made for protecting the more sensitive and exposed parts of all mechanism likely to be affected by heat from the operator's body or other source liable to lead to expansion or contraction owing to temperature changes. The cutting wheel, which was absorbent, was maintained in a moist condition with kerosene, derived from a sponge pad in contact with its edge. Hence the heat produced by the operation of grinding was reduced to a minimum.

In the course of the final finishing work upon the ratchet wheel, the whole of which was effected with the diamond charged discs already described operating with cuts of .0001 in. or less, a greatly improved grinding frame (not shown in the photograph) for holding the grinding cutters was used. Hence the combined outfit worked with such precision that it was possible to grind completely round a circle of 540 teeth and find hardly any appreciable loss upon the wheel cutting edge due to wear, although the operation involved over 2,000,000 revolutions of the grinding disc. A result of such a nature would have been quite impossible without the aid of the special appliances with which it was effected.

Reference to one or two other details affecting grinding operations may here be made. In order to save time, the angular feed of the ratchet through a tooth space was effected by means of the tangent wheel during four-fifths of the time occupied in the process of grinding out the teeth. During the finishing process, however, in order to eliminate all stresses, the tangent wheel was thrown out

of action and direct adjustment upon the divided circle with the aid of the microscopes was made by hand. Once this adjustment had been made for each tooth, the whole system was clamped and remained rigid during the passage of the grinding disc across the tooth face. The precaution to complete each circuit of the wheel at one operation without a break was always observed. Furthermore, every fresh traverse was commenced a quadrant to the rear of the one preceding it. Adequate provision was also made to eliminate so far as was possible the chances of error due to fatigue or interruption; the latter being by far the most difficult to provide against.

It now remains to indicate in general terms the probable degree of accuracy which was attained by the foregoing method of cutting a ratchet wheel. Prolonged tests with a view to determine the nature and extent of the inaccuracies upon the circuit of the ratchet were made. Necessarily errors are present even in the most carefully executed work of the character just described. It was hoped that, assuming necessary precautions had been taken throughout, the degree of accuracy present in the divided circle which was copied could at last be closely approximated, especially as the original errors of this circle, which had already been proved to be small, were bisected by the use of two microscopes in the adjustment made for every tooth cut.

Among the various tests made to determine the extent of remaining inaccuracies, was one which involved the use of a test indicator, not unlike the one already described and used for testing the screw. In this case, however, it was made and fixed so that it engaged the working face of a tooth similarly to the way in which the pawl engaged it. It was so fixed that, as the ratchet wheel was moved on the ruling engine by the pawl, it engaged first the teeth distant 180° from the pawl, and readings were taken. Then it was placed at other distances as required in the usual methods of calibrating divided circles. This test was carried out upon the ruling machine under conditions, so far as individual teeth were concerned, analogous to those in operation when ruling. The magnification used to detect movement of the index in the field of the microscope was such that a movement indicating an error of one-thousandth part of a tooth interval could be read with ease. The result deduced from a series of tests by the above method indicated that the maximum error of any single tooth throughout the circumference of the ratchet was less than one-600th part of a tooth space and no periodic error was perceptible. Unfortunately the limits

of this paper preclude any detailed statement concerning the manner in which these investigations were carried out.

3.—The Thrust Plate.

The thrust plate or bearing surface against which the screw rotates is of great importance, in that any imperfection or weakness of its surface or any diversion from a strictly normal position, of even a small area of its surface, may result in some error or slight disturbance of the screw which is almost inevitably communicated directly to the ruling. Hence a thrust plate must be made of material combining the properties of compactness, hardness, toughness and durability in a high degree. This material, whether natural or artificial, must also be such as is capable of receiving the highest possible optical finish, that is, with respect to the perfection of its working or bearing surface. The importance of these requirements will be appreciated when it is borne in mind that errors resulting from imperfection of a thrust bearing will be periodic and if so an error of amplitude less than .0000005 in. would be quite appreciable by its effect on the finished grating. Thus in the selection of a substance suitable for a thrust surface we are restricted to an extremely limited choice of material. Naturally, to those familiar with the limitations and requirements involved, the diamond is at once suggested as the most likely substance to adequately fulfil all the demands made upon it. Unfortunately a diamond of a suitable size and shape for the screw thrust of a ruling engine would be difficult to procure, extremely costly and almost impossible to work, without professional aid, to the requisite perfection of surface demanded. Of other substances we only propose to mention those of which we have had actual experience, and know wherein they failed to meet requirements. Naturally, of the substances experimented with, only the most perfect examples obtainable were used. These included the hardest steel, crystalline quartz, agate, topaz and sapphire.

The steel thrust plate was promptly discarded; though hard and tough and worked to a highly finished surface, it required lubrication to prevent seizure and this at once introduced instability, owing probably to the varying thickness of the oil film. Moreover, with steel against steel (the screw terminal face also being steel) signs of wear were soon apparent. The two examples of quartz which were tried, afforded, for a time, some promise of success and permanence; eventually, however, minute circular scratches or

grooves appeared on the area of contact with the screw facet, which led to their rejection. Topaz, which is only a trifle harder than quartz, and not so tough as the variety of quartz known as agate, likewise failed, and probably from the same cause as the latter.

With respect to sapphire, this was actually one of the first substances made use of, and was only temporarily discarded because of the difficulty of working up a bearing face to the requisite perfection. A second attempt to prepare a fine crystal slab of this gem, after the rejection of steel, agate and topaz, was rewarded with a greater measure of success; the result from the second attempt being a finely polished optically true surface, over a central circular area of the crystal $\frac{3}{8}$ in. in diameter. This face, which was free from defects, either of its crystalline structure or those arising from the process of working it, was formed on the face of a square slab of sapphire $\frac{3}{4}$ in. in diameter and under 3-16 in. thick. Two sapphire thrust plates have been successfully prepared. One of them, which is circular in shape, has been cut from a synthetically formed crystal of sapphire. The latter is somewhat easier to work than the natural gem, probably because the crystalline cleavages are less developed. The artificial gem, however, has the disadvantage of being less perfectly annealed, and, in consequence, requires greater care in working to avoid fracture. The following outline of the process of working a true sapphire thrust face may be worth recording, as it differs from the lapidary's method of working such gem faces.

It is necessary in the first place to secure a good sapphire gem stone, its colour is immaterial; it should, however, be fairly large and quite free from cleavage fractures and other similar defects. The work of slicing and roughly cutting to shape is done after the method followed by the lapidary; the grinding and polishing of its faces requires more exact treatment than he usually gives to these operations. In order to obtain good surfaces, truly worked and free from scratches or other defects, three small laps were first prepared and ground true on one face. One of these laps, made of gun metal, was used, with finely crushed and separated diamond powder, to grind up the faces and edges of the sapphire plates until they were fairly smooth and parallel. A second lap, of steel in this case, with still finer diamond powder, sufficed to finish off one ground face until it was free from the scratches and pitting remaining from the preceding grinding. A third lap of pure tin, with a carefully prepared face, was now used for polishing the already optically true face of the crystal; the polishing material

being extremely fine diamond separated in oil. If the polishing operation is properly carried out it leaves the surface of the crystal optically true, scratchless and with a brilliant polish. The outer zone of the rectangular face of the crystal was next turned off in the lathe, with the aid of a diamond tool, leaving the central area circular in outline and slightly above the surrounding face (see Fig. 1, Plate XVI.). The task of grinding and polishing the plate was throughout controlled and corrected from time to time, as required, with the aid of a small test plane, in order to ensure the best possible result. Any trace of error, when tested in this way, should nowhere exceed some small fraction of a wave length. This condition is attainable with time, patience and a moderate amount of manipulative skill.

It remained now to provide for the *Mounting* and *Adjustment* of the thrust plate prepared as described.

With respect to the former, viz., *Mounting.* The plan adopted for mounting the prepared thrust plate was as follows:—A block of machined cast iron was first prepared. This in elevation was triangular in outline with rectangular base and perpendicular face. The base was $1\frac{1}{2}$ in. square, the perpendicular face 2 in. high. Plate VI. shows the position of the thrust in relation to surrounding parts of the machine; also the method of its attachment to the bed. Fig. 1, Plate XVI., is a photograph, slightly enlarged portion of the perpendicular face of the block, the upper part of which shows the method of attaching the crystal plate to its bed. This attachment was effected with the aid of a small rectangular frame the inner edges of which were undercut to fit the bevel upon the edges of the crystal plate. The latter was then inserted into the frame in which it was embedded with a suitable cement composed mainly of shellac. By this means the thrust plate is made both secure and rigid within its frame without undue strain, while at the same time its face is adjusted approximately perpendicular to the base of its support.

Final adjustment of the thrust plate and screw thrust.—As there is a mutual relationship between the sapphire thrust plate and the screw thrust, their respective adjustments may be treated concurrently.

The shape of the screw thrust finally adopted was that of a blunt cone of hard steel with a small flat termination, the diameter of the latter being about .1 in. This form of thrust, up to the present, has behaved satisfactorily and promises to prove permanent, as it has now been in use for a considerable time.

Although it may not be absolutely essential that *both* thrust faces should be strictly parallel and perpendicular to the screw axis, one of them must be exactly so placed and the other as nearly so as possible; hence the adjustment of both was effected as part of the same operation.

In the first place, the cone and flat of the inserted screw thrust was ground with all due precaution in the lathe and a surface approximately perpendicular to the axis of the screw was obtained. This, however, was not accurate enough for the purpose required and, as the further adjustment of the end of the screw was related to that of the sapphire face, the method adopted for their mutual correction will be explained with the setting up of the thrust block. In order to obtain a close approximation to its true position the sapphire thrust block was first set up with the aid of the usual mechanical appliances. More exact adjustment was obtained by the use of a well-known optical method of setting up a mirror normal to a rotating axis. A round bar of steel, rather longer than the screw, was accurately ground at each end to the same diameter as the screw bearings. This bar formed the counterpart of the screw without its threads, and hence could be used with greater freedom and without risk. To one end of the bar, representing the thrust end of the screw, a truly plane quartz mirror was attached by means of a slightly plastic cement. This rod was placed in the bearings of the ruling machine, and the mirror firmly pressed without rotation against the sapphire thrust face. The rod was then transferred to V bearings so placed that by means of a reading telescope of fairly high power a distant illuminated disc with cross wires and perpendicular scales could be viewed by means of the quartz mirror. Rotating the rod caused the image of the cross wires to move in the field of view unless the surface of the mirror was normal to the axis of the rod. Definite movements corresponded, as was soon found, to definite errors in the thrust and so by means of trial and error the thrust was, after considerable work, adjusted until the image of the cross wires remained fixed during a rotation. As the sapphire thrust had already been adjusted to a nearly correct position, these later adjustments were only of microscopic dimensions. For adjustment in a horizontal plane, the small movements required were effected with the aid of two micrometer screws placed one on the right and the other on the left of the thrust block to which they could be made to impart a minute rotary movement. Adjustment of the block in a vertical direction was obtained by slightly grinding

either the front or back surface of the block base as required: The effect of every adjustment was determined with the telescope and was followed by such further alterations as was indicated by the motion of the image of the cross wires. The process of correction was continued in this way until the telescopic image remained steady within the limits of experimental error. Finally the mirror was removed from the rod representing the screw and was placed upon the actual screw of the machine and a slight further adjustment of the thrust plate made by the same method.

As the thrust block could now be removed and restored to its position between the micrometer screws with certainty, it was taken out and the surface of the sapphire coated with a very thin film of a solution of eosin in alcohol and water, applied with the aid of a fine smooth needle. In this way an immeasurably thin film of stain or colour was left upon the polished sapphire face. On replacing the block in its former position the thrust facet of the screw was gently pressed into contact with the sapphire and rotated through a very small angle. The effect produced was carefully examined with a powerful magnifier and the exact position and area of contact determined; this showed that the surface of contact was not central but was limited to one part of the thrust near its edge. Another test with the screw 180° from its former position definitely indicated that the screw facet was principally at fault. Correction of this defect was obtained by inserting a thin parallel plate of quartz between the thrust plate and screw bearing; one face of the quartz was polished the other smoothly ground, the latter being in contact with the steel thrust. The screw was then slowly rotated in contact with the plate which was constantly moved, revolved and reversed between the thrusts. The result of these combined movements was a delicate abrasive action upon the screw facet without any corresponding effect upon the sapphire thrust face. In this way, with care and judgment, fairly uniform central contact of the screw thrust face with that of the sapphire was obtained. It should be understood that the amount of material removed from the bearing surface of the thrust by this process was probably not more than one or two wave lengths in thickness. These correctional operations, which extended over a considerable period, with intervening trial rulings, resulted eventually in the almost complete elimination of any remaining periodicity.

4.—The Diamond.

Under this heading it is proposed to allude briefly to the minor but yet essential mechanical appliances for adjusting and controlling the movements of the diamond during the act of ruling. The principal features of the mechanism of the ruling carriage have already been described and a short account given of the sequence in which certain movements took place during the process of ruling. (See page 49.) The following remarks so far as they relate to the mechanism controlling the diamond, are supplementary to the previous description.

Figs. 2 and 3, Plate XVI., are photographic views, back and front respectively, of the ruling mechanism. Fig. 3 shows in some detail the following parts:—(1) The bar of hard steel of square section supported in a steel frame with the aid of two hardened conical screw pivots which permit of movement in arc of a few degrees. Secured to this bar on its lower face there is a plate of hard steel (37),[1] triangular in shape, in the centre of which the principal dash well (42) is placed, the diamond holder being secured to its apex. This holder is a small hollow cylinder (38) of aluminium with solid end whose walls are partly slotted through to hold the diamond clamp (39). The attachment of the solid end of the cylinder to the triangular steel plate provides for rotational adjustment. Three important movements of the diamond are provided for in this form of holder, viz.: (1) axial rotation of the rod or pin on which the diamond is mounted; (2) movement of the clamp block 39 in a vertical plane parallel with the direction of the lines ruled; (3) movement in a direction or plane at a right angle to the direction of the lines ruled. All these movements are important in the preliminary setting up of a diamond. Two steel rods complete the control outfit of the diamond; one of these (4) is made to lift the diamond from the plate after each line has been ruled, the other supports the plunger of the dash well and is not shown by the photograph.

In Fig. 2, Plate XVI., we have a back view of the diamond carriage and its fittings. Here may be seen an oblong block of metal secured to the suspension bar and serving as a counterpoise to the triangular frame and fittings of the diamond holder. This block in addition to acting as a counterpoise is fitted with two additional oil wells and dashers and also carries a projecting

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1 The numbers refer to positions and parts indicated by corresponding numbers on the plan of the machine, Plate VI.

threaded bar on which additional weights are screwed for regulating to a nicety the pressure upon the diamond ruling point. The ruling system is thus completely controlled and balanced upon the two hardened centres of the suspension frame.

Considering the long period during which interest has been more or less centred upon fine ruling and the means for accomplishing it, either for use as spectroscopic gratings, test rulings or micrometers—all of which require very fine accurately spaced lines—but little has been written concerning the diamond with which such ruling is effected. As already mentioned, Nobert guarded with jealous care his knowledge of the subject, the result of years of patient work, and which he regarded as an important secret known only to himself. Upon Nobert's death his ruling machine passed eventually into the possession of the late Dr. von Heurick, of Antwerp, who was interested in ruling in its relation to the microscope. Some years ago the writer had correspondence with Dr. van Heurick, who stated that he had spent some time in trying to rule test plates similar to those prepared by Nobert, but without success. In the course of his experiments he had had prepared by one of the most skilled diamond workers in Antwerp a set of diamonds exactly similar to those found with the Nobert machine and with which Nobert presumably ruled his plates. Dr. van Heurick generously presented to the writer three of the prepared stones. Whilst it was a matter of great interest and pleasure to obtain these diamonds, the knife edges of which appeared to have been exquisitely worked, the results obtained by their use were most disappointing. Indeed the lines obtained with these carefully prepared knife-edged gems were quite unsuited for any but the coarsest ruling. Prior to this experience with the diamonds from Dr. van Heurick, an interesting paper by Profesor Rogers, of Baltimore, U.S.A., had appeared. This paper contained much information concerning the operation of a ruling diamond with prepared knife edges and with edges resulting from fracture; the latter were stated to be more or less unsatisfactory. His method of using either knife edges or fractured splinters appears to have been diametrically opposed to that of other workers; certainly to that of the writer.

Professor Rogers, for example, emphasises the statement that a ruling diamond should produce, or did in his experience produce, a distinct and characteristic sound during the act of ruling. So familiar had this note become to his sense of hearing that he was accustomed to judge of the behaviour of a particular diamond by

this characteristic note. The writer's experience, extending over some 20 years, of the behaviour of a diamond during the act of ruling is that its action should be practically free from any appreciable sound or note of any sort. Anything approaching a distinct hissing or singing note has invariably been regarded as evidence that the lines thus being ruled would show, when examined miscroscopically, some indication of a vibratory or chattering effect upon the surface ruled, and that the "life" of a diamond operated under these conditions would be comparatively short. Apart from this somewhat contradictory position with respect to the experience of others whose work has extended over a considerable period, the article referred to contains much interesting information.

One other reference to the action of a diamond when ruling appears in the collected Researches of the National Physical Laboratory, Vol. VIII., 1912. The results therein embodied have presumably been derived from experience in ruling with the Blytheswood Engine. So far as the *method* of using a diamond is there explained, the writer is in full agreement; with certain other statements and procedure there recorded his experience is at variance.

With respect to the choice and selection of diamonds suitable for ruling. After an experience extending over 20 years the writer prefers diamonds found in the diamondiferous drifts of New South Wales. These stones are both harder and tougher than any other he has hitherto obtained. Both Cape and Brazilian stones have been tried; also the so-called black diamond, carbonado and "bort," nearly all the varieties of which are more or less crypto-crystalline and unsuited for ruling except for the coarsest lines. The best Australian stones for ruling work are those showing smooth, bright crystalline faces, the simpler octahedral forms affording the best results. The more complicated the crystalline structure, the fewer the splinters adapted for ruling obtainable from a given gem. Cleavage fragments intersecting the smooth outer surface of a stone frequently give excellent results and are very durable.

For breaking the stones, a small mineralogical hammer and hard steel anvil are required, with provision to prevent loss of flying fragments. Straight smashing blows must be avoided or the stone will be reduced to dust. A dragging blow ranging from a sharp tap to one of considerable force may be used; changing the position of the stone until success is attained. 20/- worth of selected stones will serve for a lifetime if properly used. Once a stone has been

broken into several pieces a gentle blow will serve to reduce the larger fragments to a suitable size for ruling purposes. The broken splinters are placed in a watch glass and roughly sorted from the small debris. The selected pieces are then carefully examined under a higher magnification and those showing good knife edges and cleavage faces intersecting a smooth outer crystalline face, may be selected for trial. After a sufficient number have been thus obtained they are mounted in cup-shaped depressions drilled on the ends of short pieces of straight hard brass of the correct gauge to fit the holder of the machine. The depressions in the rods are partly filled with a hard tough cement rendered plastic by heating. The diamonds are placed in position upon the cement which is gently heated and moulded around the diamond fragment until the latter is deemed to be secure. The whole of this work is done with the aid of a microscope and requires both care and experience. A popular notion concerning diamonds is that they are so excessively hard that they may be handled with impunity. This notion is speedily falsified upon a very short experience of the fragile edge of a diamond suited for ruling lines at the rate of 20,000 to the inch.

When a few promising fragments have been cemented in their holders they are placed in a small ruling machine, and tested with respect to correct centring and inclination or angle of the knife's edge to the surface being ruled. The setting of a diamond for ruling is almost the reverse of that required when it is used as a turning or cutting tool upon a lathe. When used for the latter purpose, it is required of a diamond to definitely remove materials from a given surface. As a ruling instrument the diamond usually only slightly displaces or compresses material according to the nature of the material. The lines, for example, represented in the photographs, Plate XVII., are nearly all examples of slight displacement or compression. Moreover the diamond is not rigidly held during the act of ruling but is trailed along the surface operated on.

The pressure exerted upon the cutting edge of a diamond must be carefully proportioned to the length of its contact with the surface ruled, and this does not usually in the case of fine lines exceed .002 in. The angle the cutting edge makes with the surface ruled upon must at the same time be taken into account, as this angle has an intimate relation with the length of contact on the ruled surface and hence with the pressure required for a satisfactory line.

With respect to lines suited for diffraction gratings they must be clean and sharply defined and for normal light distribution in the different spectra the groove should be symmetrical or isosceles with respect to the ruled surface. The length of service of which a diamond is capable depends very greatly upon the treatment to which it is subjected. The shock which a diamond gets due to its fall at the commencement of each fresh line has a more detrimental effect upon its cutting edge than the wear due to the act of cutting. A ruling diamond in the case of grating ruling should have its fall restricted to less than .02 in., and the blow from even that height must be carefully moderated with damping devices or the character of the line will change as the ruling progresses and the resulting grating rendered valueless.

In order to illustrate several of the most common defects resulting from the improper adjustment of a ruling diamond, a few photographs of rulings have been prepared and are shown in Plate XVII. Two of these photographs (Figs. 1 and 2) were taken to show the character of lines resulting from a correct adjustment of the ruling diamond. Only the starting and terminal ends of the lines were photographed as these show most clearly that the diamond has been correctly adjusted. These lines were ruled at the rate of 1000 to the inch by hand which accounts for any slight irregularity. The diamond with which these lines were ruled had been in use for some weeks and had ruled several hundred thousand lines with apparently no change in its condition. Fig. 3, Pl. XVI., shows a group of lines ruled upon speculum metal with a slight displacement of the diamond edge from a position parallel with the line ruled and also slightly tilted from the perpendicular. The effect produced is sufficiently striking. The diamond, in cutting these lines, appears to have acted somewhat after the manner of a ploughshare, the material removed coming away in a thread-like form from certain areas of the metal surface. Upon readjustment the line appeared normal and without a break. The angle made by the knife edge with the ruled surface was then increased and the effect which was produced appears in Fig. 4. Here the lines ruled are fairly symmetrical but somewhat ragged on both edges; some of the material removed from the lines appearing as minute spirals. Fig. 5, Pl. XVII., is a photograph of lines ruled with a carefully adjusted diamond at the rate of 9000 to the inch. Lines of this quality would be well suited for grating work up to 20,000 lines per inch. Two examples of finer ruling are seen in Fig. 6, the

only difference between these lines and the preceding (Fig. 5) being one of pressure upon the ruling edge. Such rulings are of course much too fine for grating work.

In *conclusion* the writer may be permitted to say that the construction of a Ruling Machine is not the straightforward piece of work which this brief account may appear to indicate. Difficulties were met with from time to time which frequently necessitated a modification of preconceived ideas and intentions. The work throughout afforded but little opportunity for economy with respect to either time or labour. Practically every portion of the machine required one's best effort to be bestowed upon it; as each part was either in itself of sufficient importance to call for this or was directly related to other important parts.

It remains to express my great obligation to several gentlemen who afforded unstinted help whenever appealed to. During the early stages of the work, I was especially indebted to Mr. W. Stone, Chief Electrical Engineer of the Victorian Railways, who generously undertook the labour of cutting both the screws and grinding nuts, which required a more accurate and powerful lathe than any at my service, and who, throughout subsequent operations, was ever ready with help, suggestions and friendly criticism.

I am likewise under even greater obligation to Professor T. R. Lyle, F.R.S., who, from the initiation of the project for building a machine, interested himself and others in a variety of ways with a view to such assistance and encouragement as he considered would best help forward the undertaking. Later he induced the University Council to permit him to make provision in 1914 for housing the machine in his laboratory at the University, and for carrying on the work of its completion and improvement under favourable conditions. Since his retirement from the Chair of Physics in 1915, he has been immediately and actively associated with all the later improvements, many of which are due to him. This applies especially to the calibration and adjustment of the Ratchet wheels, and the elimination and correction of errors of the screw and its thrust plate. These operations were prolonged and tedious, but were greatly simplified by his mathematical insight and experience which, to me, were an inestimable advantage and materially reduced the mechanical work involved.

My best thanks are also due to Professor E. W. Skeats, who, during my association with his Department, unreservedly placed at my service all the facilities his workshop and laboratory afforded.

I am greatly indebted to Professor Orme Masson, F.R.S., who as President of the Professorial Board and Dean of the Faculty of Science, used his influence for the promotion of the undertaking and whose efforts made it possible for a proportion of my official time to be given to the work. To my friend, Mr. James Fawcett, of Camberwell, my heartiest thanks are due for the time and trouble he bestowed upon the preparation of the plan of the machine appearing as Plate VI., and for several minor drawings. Finally, I am fully cognisant of the fact that I owe to the University or its governing authorities, whose consideration and generosity have made it possible for me to devote so much of my time to the completion of this work during the past three years, far more than this verbal expression of my indebtedness conveys.

DESCRIPTION OF PLATES.

Plate VI.—Plan of Ruling Engine.

,, VII.—End view of Ruling Engine.

,, VIII.—Side view of Ruling Engine—Right hand.

,, IX.—Side view of Ruling Engine—Left hand.

,, X.—Front view of Ruling Engine.

,, XI.—Fig. 1. Apparatus for refining crudely separated abrasive.

Fig. 2. Apparatus for grinding the screw.

,, XII.—Fig. 1. Alundum, average diameter of grains, 1-500 inch.

Fig. 2. Alundum, average diameter of grains, 1-4000 inch.

Fig. 3. Carborundum, average diameter of grains, 1-2000 inch.

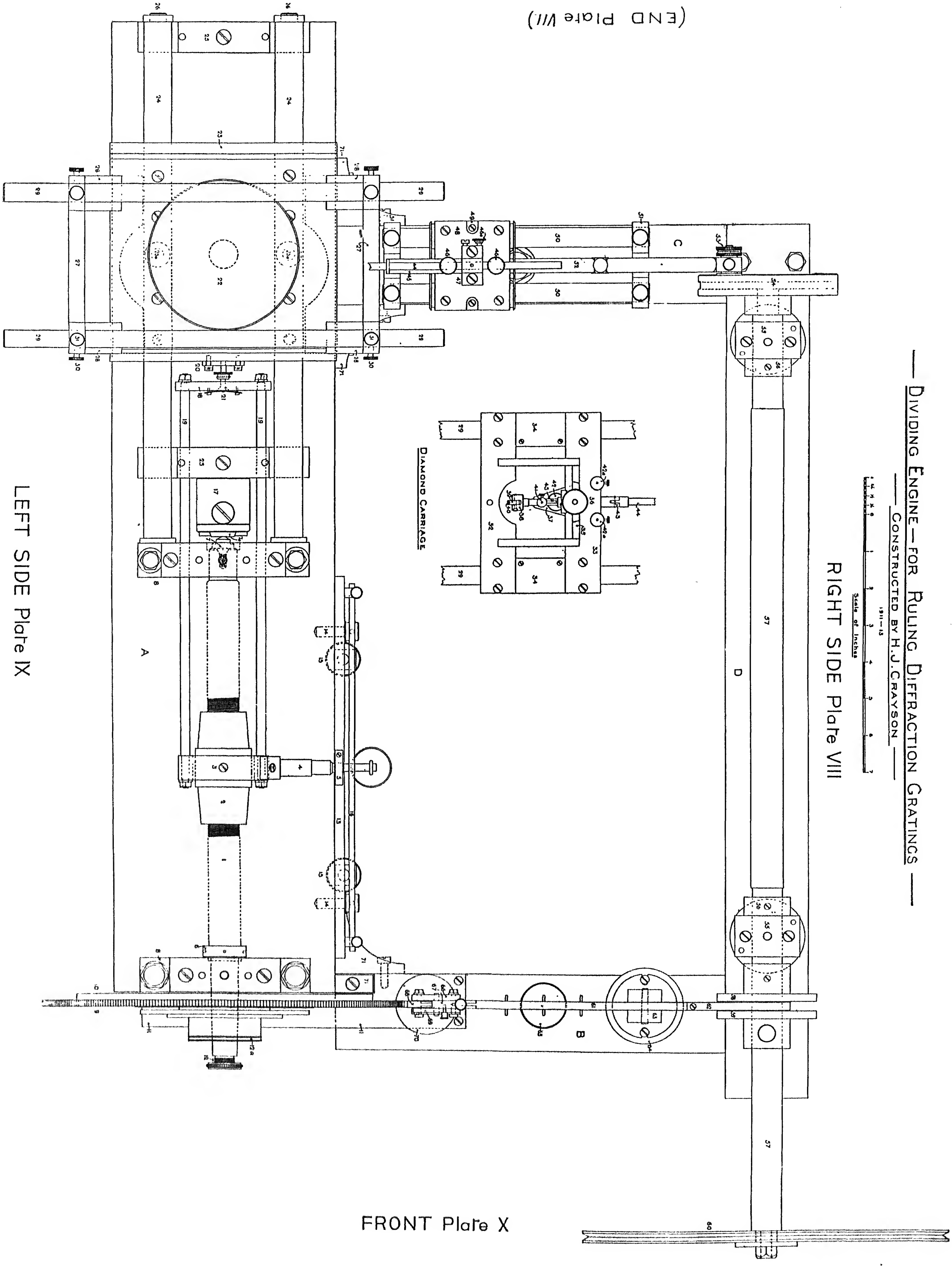
Fig. 4. Carborundum, average diameter of grains, 1-4000 inch.

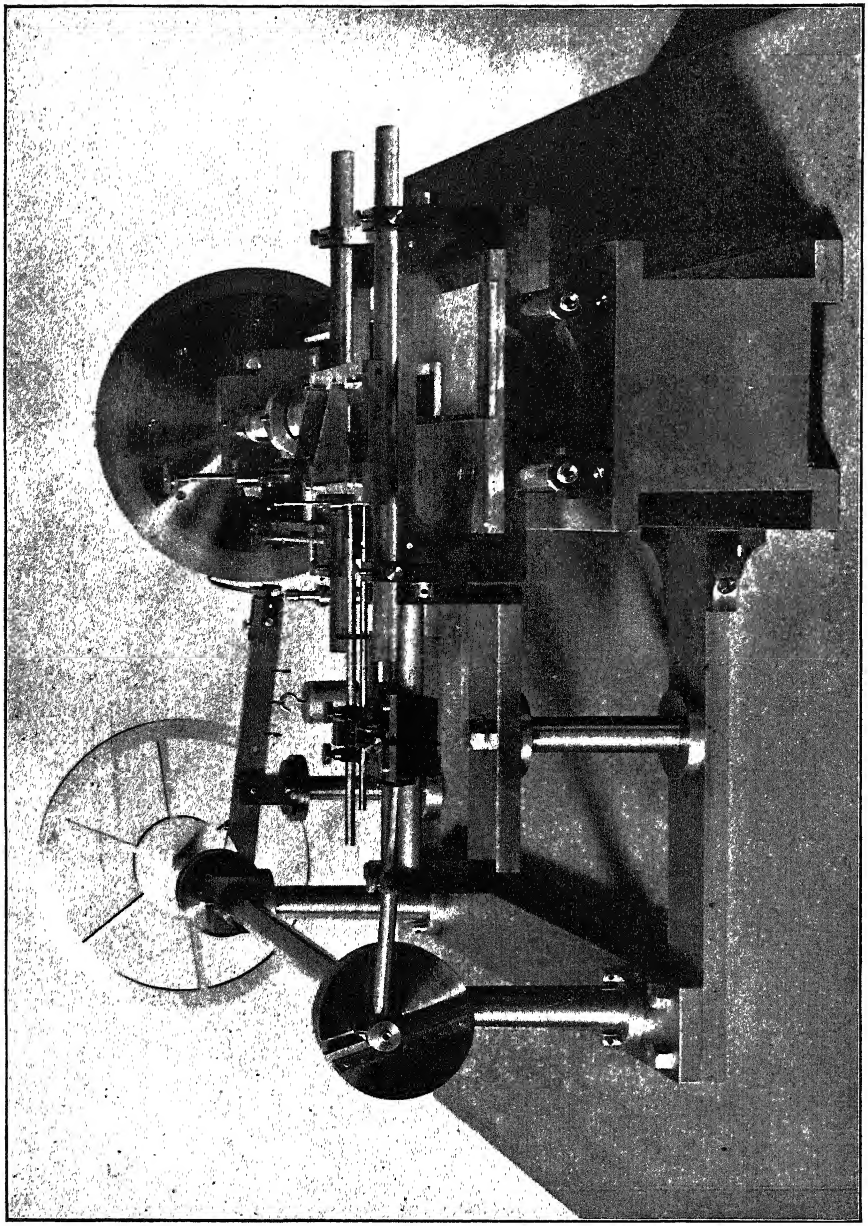
Fig. 5. Emery, average diameter of grains, 1-1000 inch.

Fig. 6. Emery, average diameter of grains, 1-4000 inch.—Figs. 1 to 6, $\times 75$.

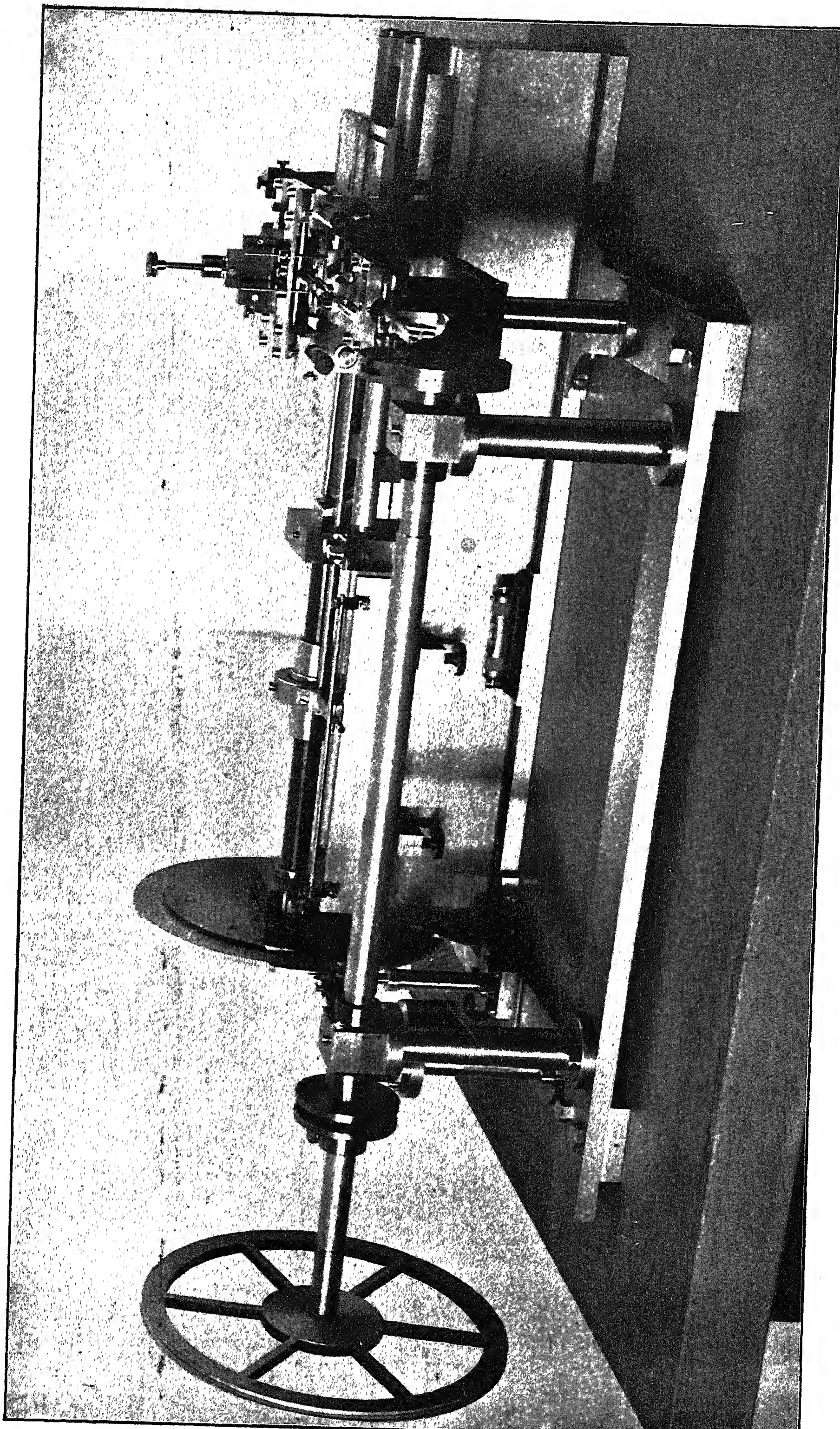
,, XIII.—Fig. 1. Curve indicating condition of screw prior to re-grinding.

Fig. 2. Curves showing progressive improvement during re-grinding.

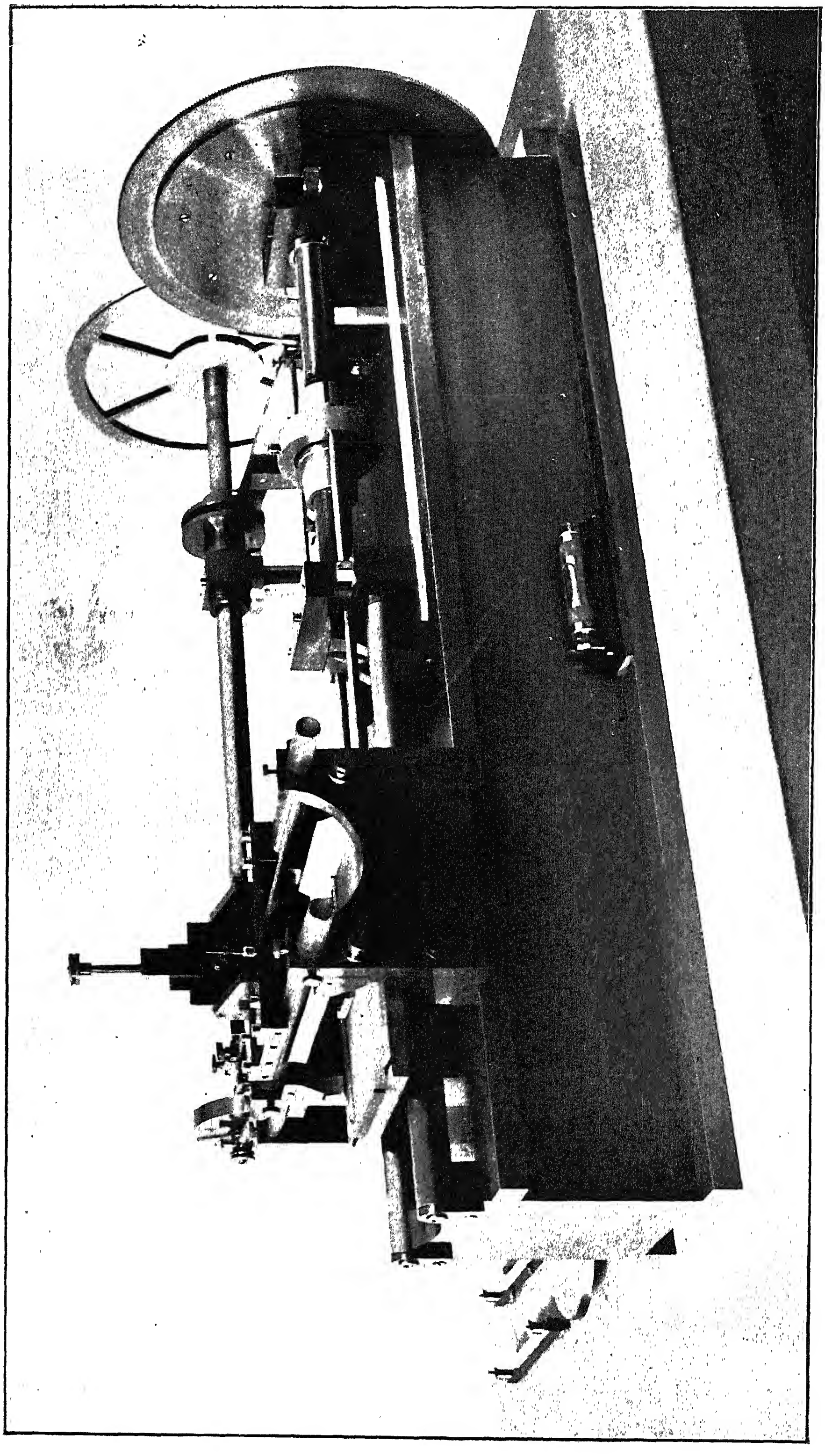

(END Plate VII)
— DIVIDING ENGINE — FOR RULING DIFFRACTION GRATINGS —
— CONSTRUCTED BY H. J. GRAYSON —
1911-15
Scale of Inches
RIGHT SIDE Plate VIII
DIAMOND CARRIAGE
LEFT SIDE Plate IX
FRONT Plate X
A
B
C
D



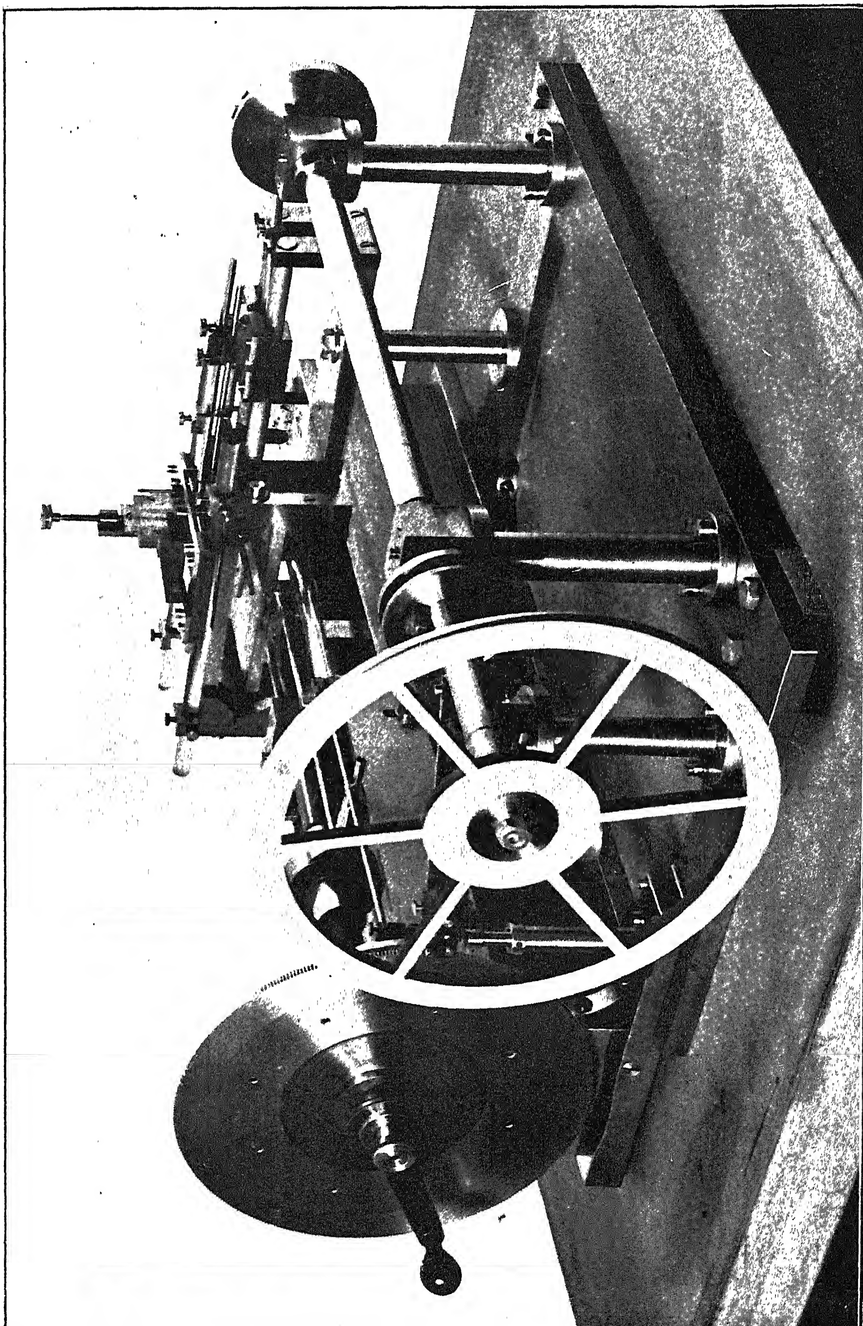
End View of Ruling Engine (Back).



Side View of Ruling Engine (Right Hand).



Side View of Ruling Engine (Left Hand).



Front View of Ruling Engine.

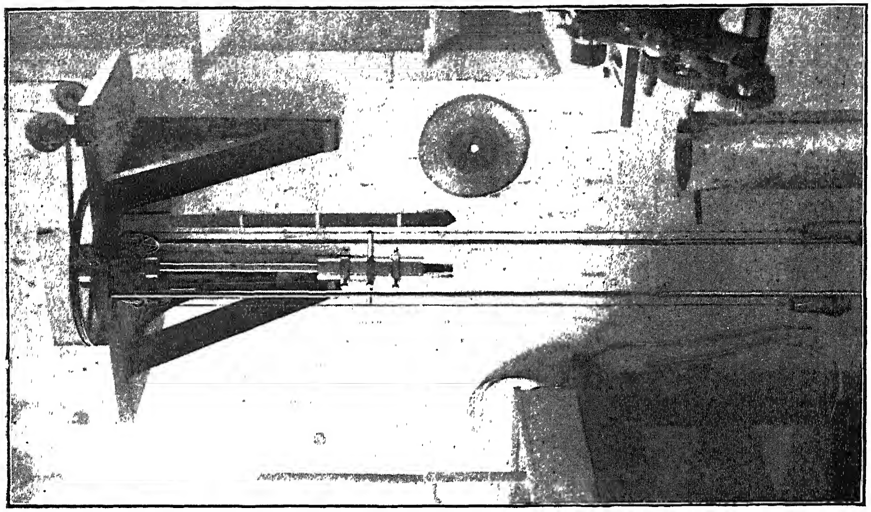


Fig. 2.

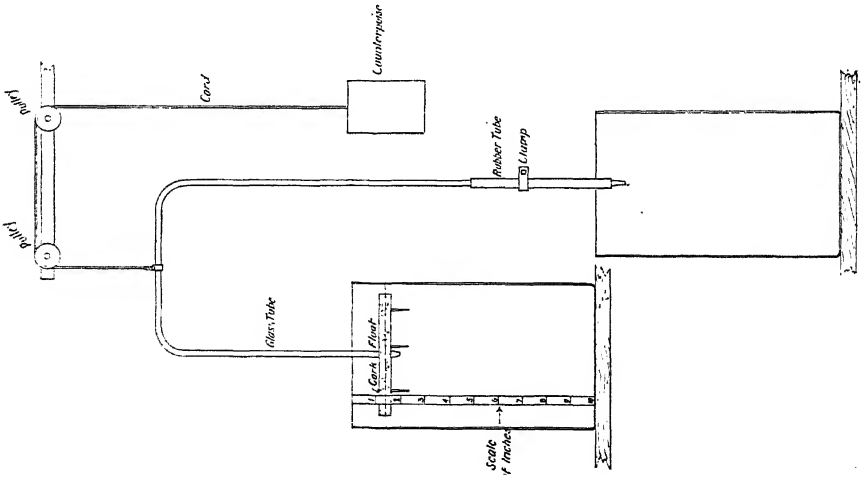

Pulley
Pulley
Cord
Counterpoise
Rubber Tube
Clamp
Glass Tube
Cork Float
Scale of Inches

Fig. 1.

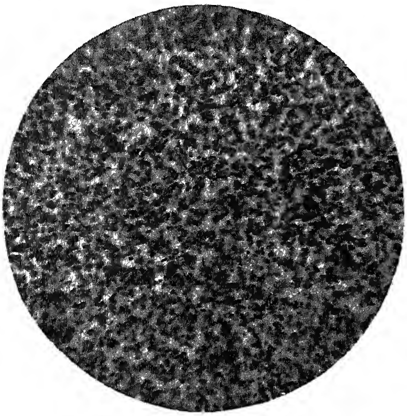


Fig 1.

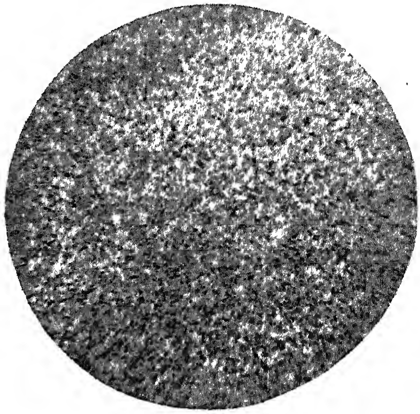


Fig 2.

Fig 3.

Fig 4.

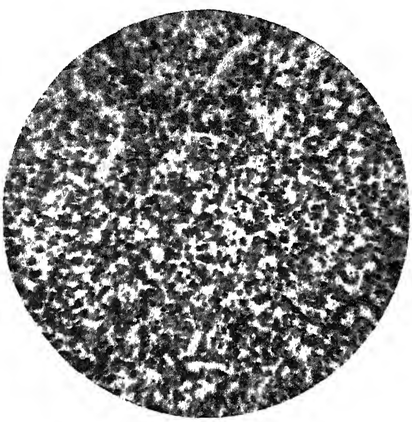


Fig 5.

Fig 6.

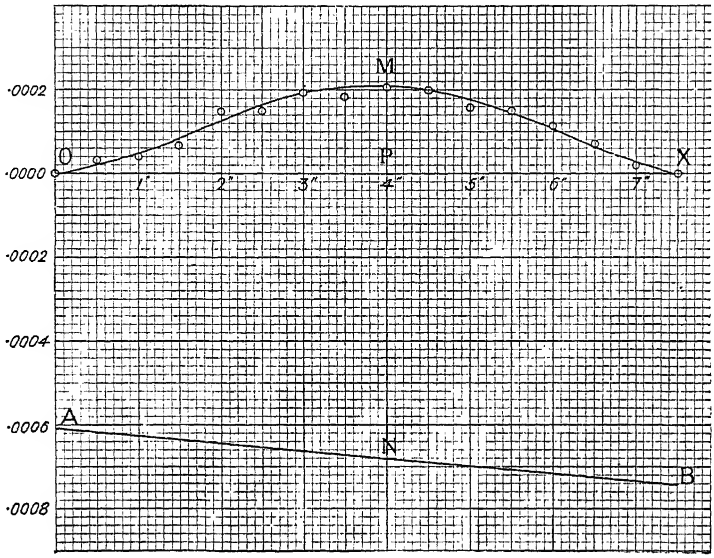


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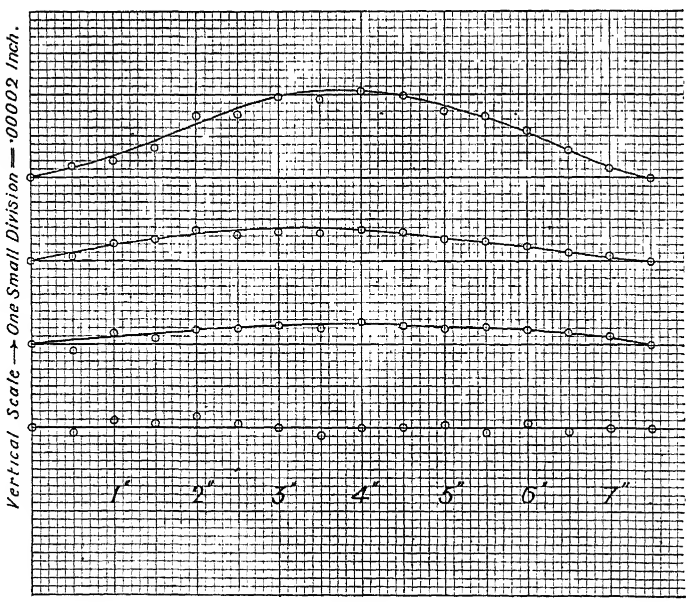
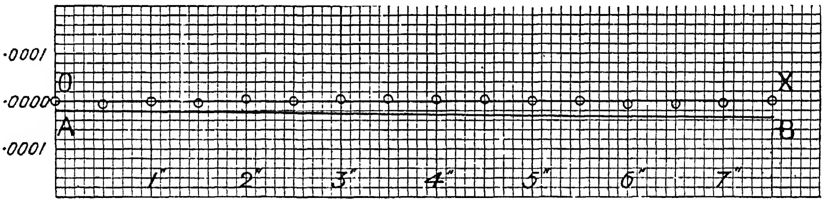
Fig. 1



Vertical Scale → One Small Division = ·00002 Inch.
1"
2"
3"
4"
5"
6"
7"

Fig 2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1"
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Fig. 1.

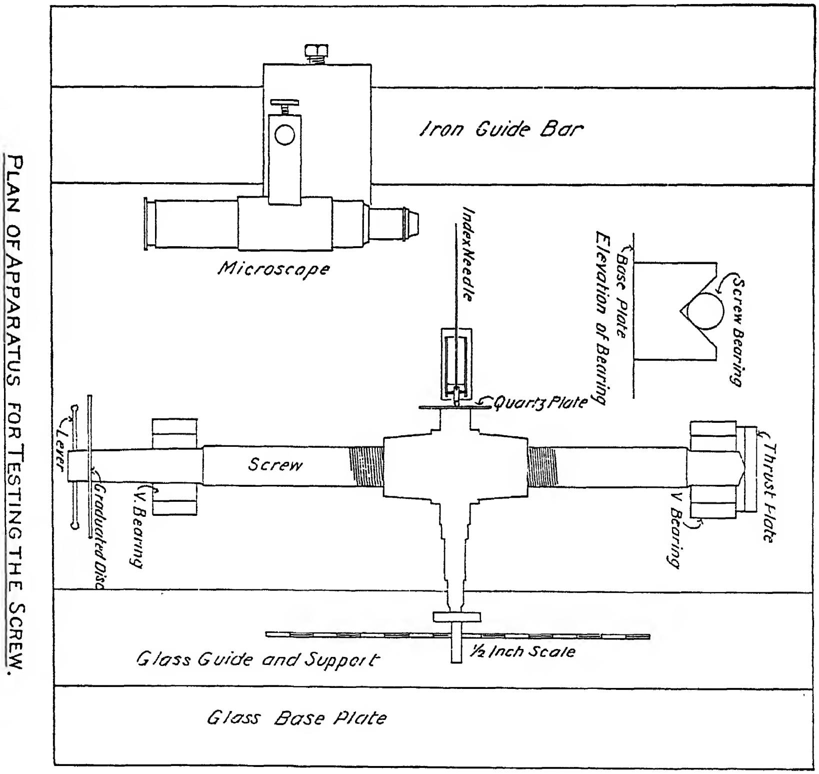
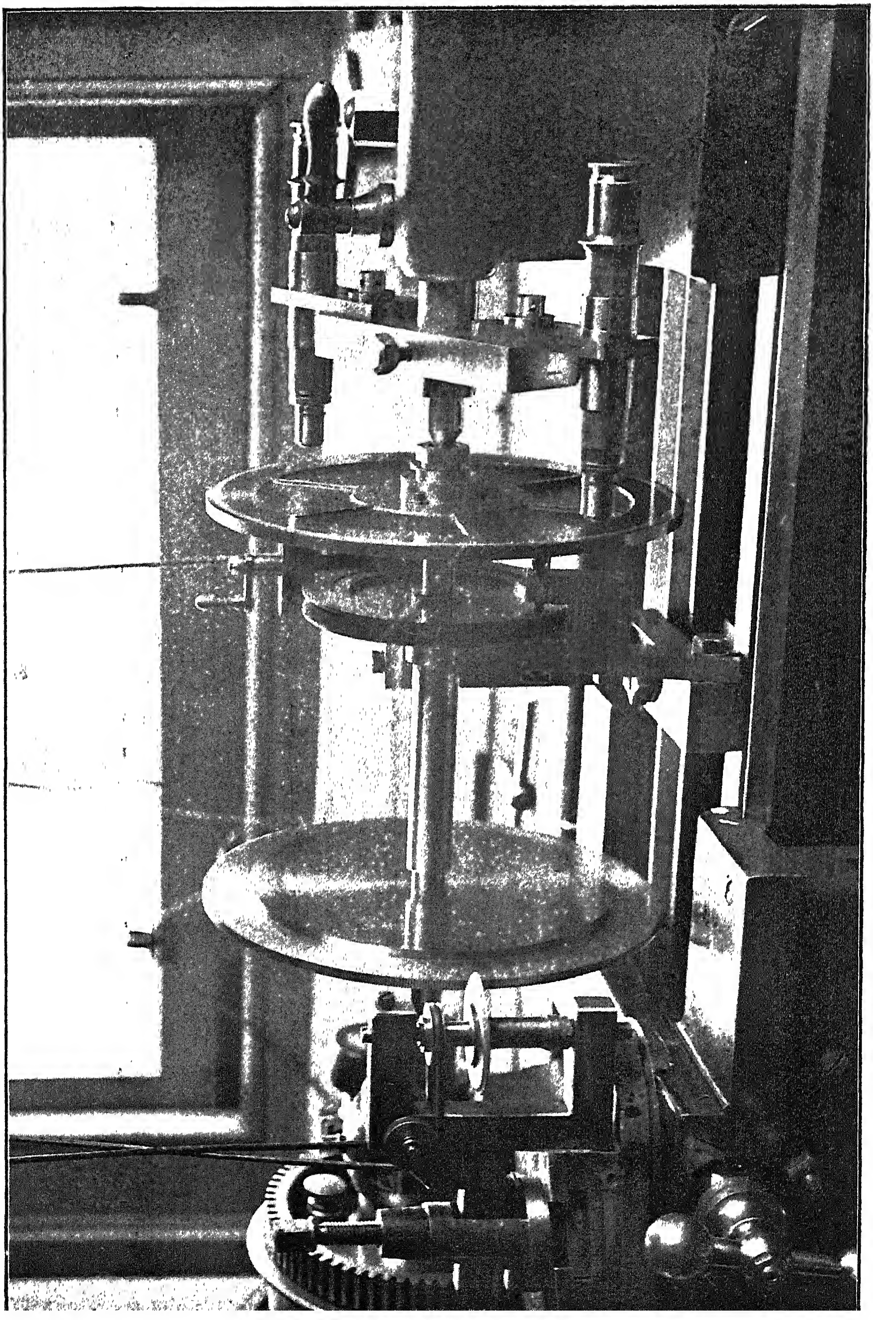

Plan of Apparatus for Testing the Screw.
Iron Guide Bar
Microscope
Index Needle
Base Plate
Elevation of Bearing
Screw Bearing
Quartz Plate
Lever
Screw
Graduated Disc
V. Bearing
V Bearing
Thrust Plate
Glass Guide and Support
½ Inch Scale
Glass Base Plate

Fig 2.



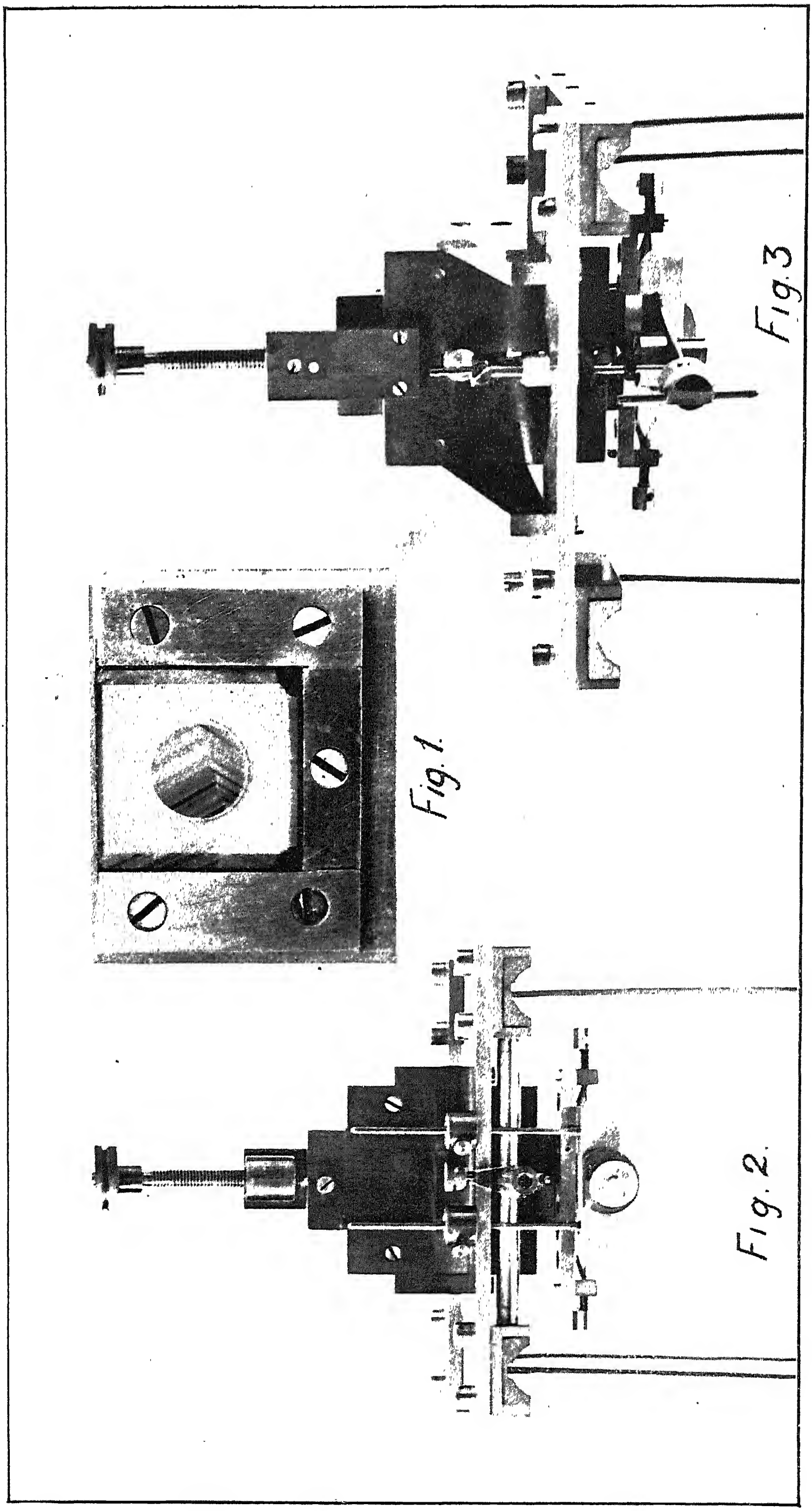


Fig. 3
Fig. 1.
Fig. 2.

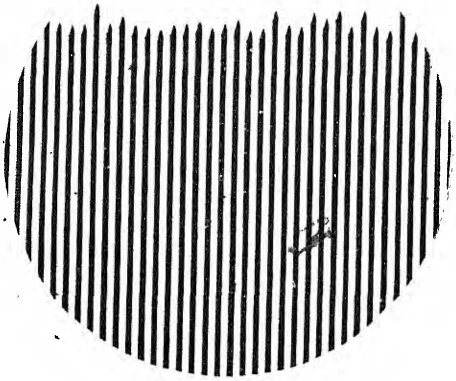


Fig. 1.

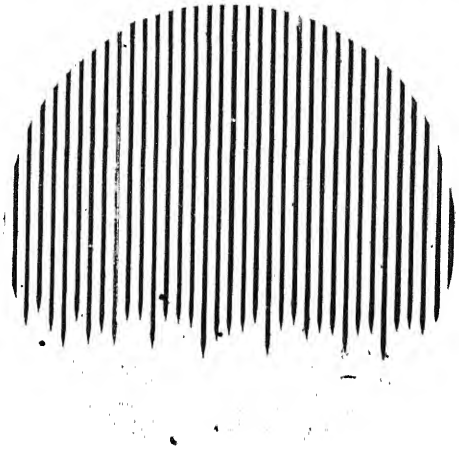


Fig. 2.

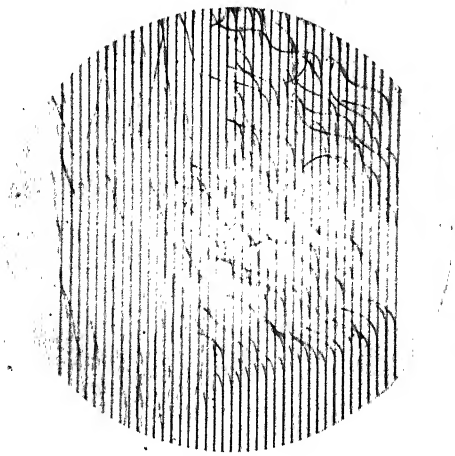


Fig. 3.

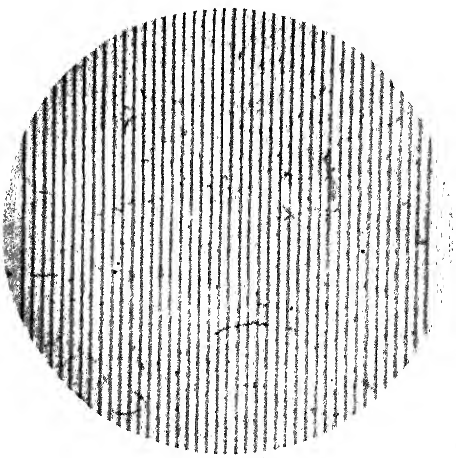


Fig. 4.

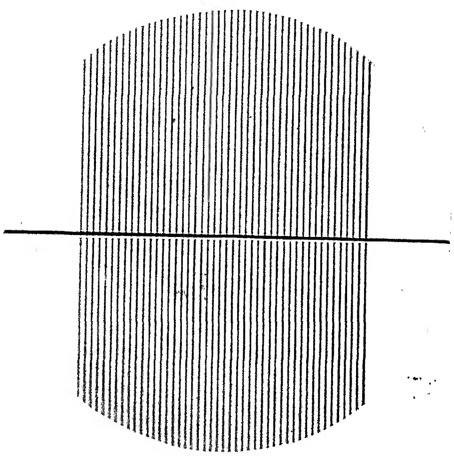


Fig. 5.

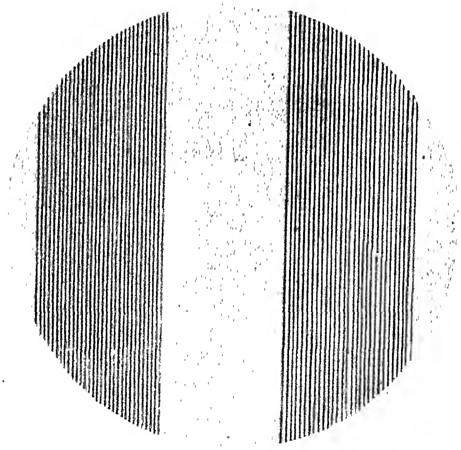


Fig. 6.

Pl. XIV.—Fig. 1. Curve showing result of corrections.
Fig. 2. Plan of apparatus for testing the screw.
,, XV.—General view of apparatus for cutting ratchet teeth.
,, XVI.—Fig. 1. Thrust block and sapphire thrust plate, slightly enlarged.
Fig. 2. Diamond carriage—back view.
Fig. 3. Diamond carriage—front view.
,, XVII.—Microphotographs.
Fig. 1. Commencement of lines ruled with a correctly adjusted diamond, × 66.
Fig. 2. Termination of lines ruled with a correctly adjusted diamond, × 66.
Fig. 3. Lines ruled with an incorrectly adjusted diamond, × 50.
Fig. 4. Lines ruled with an incorrectly adjusted diamond, × 50.
Fig. 5. Fine lines ruled with a correctly adjusted diamond, 9000 to the inch, × 300.
Fig. 6. Fine lines ruled with a correctly adjusted diamond, 55,000 (Right) and 60,000 (Left) to the inch, × 1300.

Key to numbers on Plate VI.—the Plan of the Machine.

A. Main cast iron Bed of Machine.
B. Base plate supporting ratchet mechanism.
C. Base plate supporting mechanism controlling ruling carriage.
D. Base plate supporting main driving shaft.
1 Precision screw; 20 threads per inch.
2 Steel casing of nut.
3 Ring of steel surrounding nut with pressure and transmission-rod adjustment.
4 Nut extension bar.
5 Bearing support for guiding 4.
6 Lock nut to prevent end play of screw when reversed.
7 Inserted hardened steel thrust.
8 Main bearings supporting screw with caps and bolts.
9 Ratchet wheel.
10 Shoulder plate and hub to which 9 is bolted.
11 Base plate supporting arrest pillar of ratchet wheel.
12 Lock nut for fixing handle to screw (when required).

13 Adjustable guide bar supporting 4 and 5.
14-15 Micrometer elevating screws and lock nuts of 13.
16 Guide bar arresting 4 and 5 on reversal of screw motion.
17 Thrust block with polished sapphire bearing plate.
18-19 Cross head and steel bars connecting 2 and 3 with ruling table 23.
20-21 Screw plate, swivelling bar and ball thrust joining 18 and 23.
22 Detachable circular ruling plate.
23 Slotted steel ruling table with under-carriage (latter not seen).
24 Circular steel supports of ruling table.
25 Bearing supports of 24.
26 Lock nuts connecting 24 and 25.
27 Upper portion of frame supporting ruling carriage ways.
28 Part of steel trough in which 29 lie.
29 Circular ground glass rods upon which diamond carriage travels.
30-31 Adjustment and binding screws of 29.
32-34 Steel and brass framework of diamond carriage.
35 Framework supporting ruling diamond and its adjustments.
36 Elevating screw and dovetail slide of ruling mechanism.
37 Triangular steel plate carrying ruling diamond.
38 Rotating clamp holding 39.
39 Swivelling clamp on block in which diamond holder rotates.
40 Rod or holder on the lower end of which ruling crystal is mounted.
41 Pin and clamp controlling elevation of diamond holder.
42 Dash well with oil and plunger.
43 Hinge joint connecting 44 with ruling mechanism.
44 Sliding connecting rod.
45 Guide frame in which 44 slides.
46 Screw clamps for adjusting range of motion of 44.
47 Adjustment block controlling 44.
48-49 Base plate to which guides and sockets are attached travelling upon 50.
50 Polished steel parallel guide rods supporting 44-49.
51 Lock nuts and frame supporting 50.
52 Jointed crank shaft.
53 Adjustable eccentric locking head sliding in 54.
54 Circular slotted head rotating up main shaft 57.

55-56 Bearing blocks, caps and adjustment collars of 57.
57 Main driving shaft.
58-59 Cam guides with adjustments.
60 Driving wheel.
61 Hinged steel lever bar communicating cam motion to pawl.
62 Lubricating spring bar overlaying cam.
63-64 Hinge block and main support of 61.
65 Counterpoise opposing cam action.
66-69 Frame and adjustments controlling pawls 68.
70 Base of arresting pillar below pawl frame.
71 Brackets joining B. and C. to A.

[PROC ROY. SOC. VICTORIA, 30 (N.S.), PT. I, 1917].

ART. VII.—*Abnormal Circulation of a Frog.*

BY ELLINOR ARCHER, B.Sc.
(Government Research Scholar).

(With Plate XVIII)

[Read 9th August, 1917].

During the usual dissection of the frog (Hyla aurea) by students in the Biological laboratory of the University of Melbourne, one of the specimens was found to show a hitherto unnoticed abnormal arrangement of certain vessels of the venous system

The organs were well developed and showed no trace of being affected by the altered circulation as might have been expected, especially in the case of the liver.

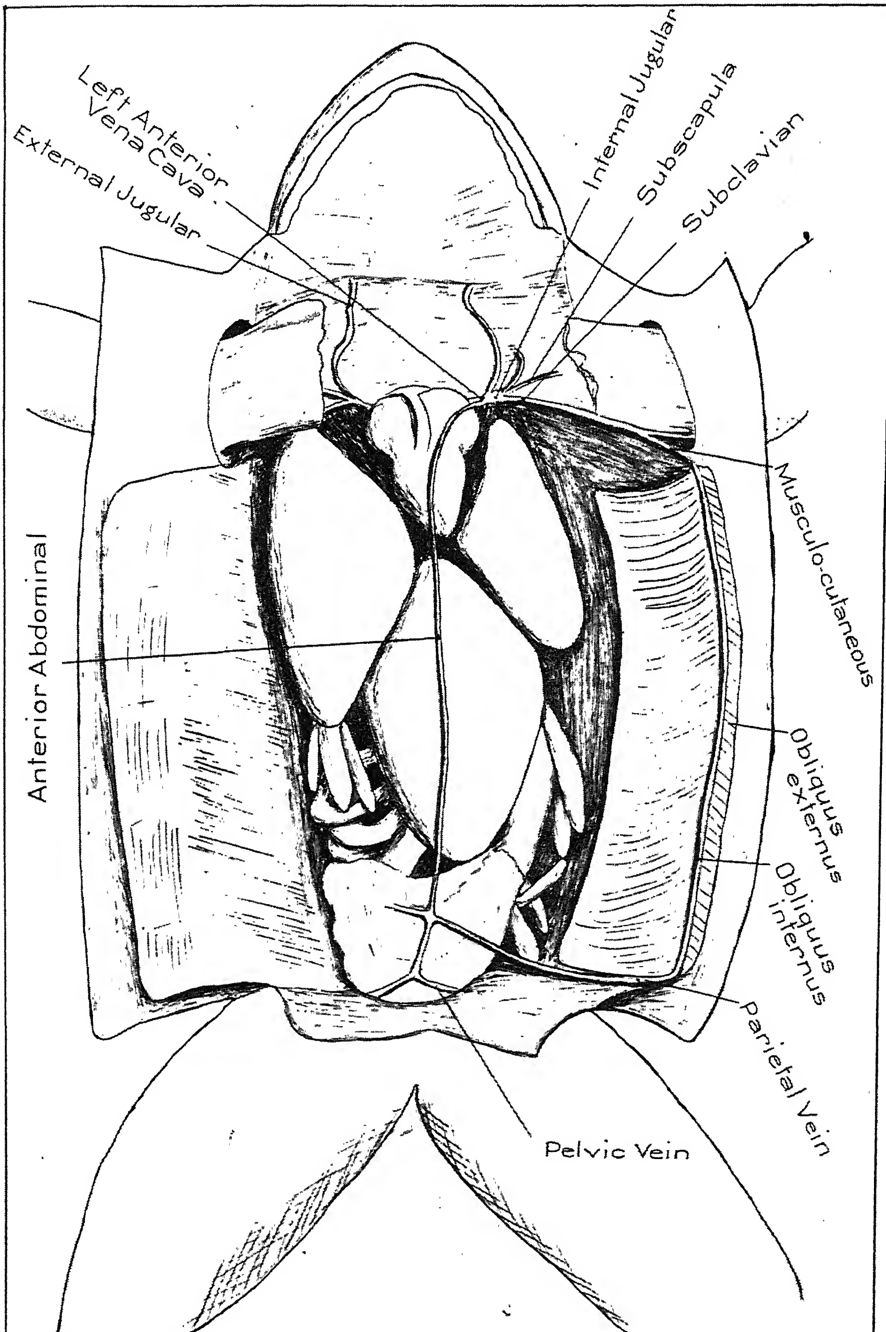
The anterior abdominal vein was the chief vessel showing the abnormality. It commenced from the two pelvics as a normal-sized vessel; it then, instead of being augmented by the two parietals, as is normally the case, passed some of its blood into the parietals on the left side, which was an unusually large vessel The parietal on the right side was normal.

The anterior abdominal beyond the two parietals was smaller than is usually the case, and was continued up the length of the body to the heart, across the liver and across the ventral surface of the heart, entering the left anterior vena cava at the point at which it is formed by the large anterior veins.

The hepatic portal opens directly into the liver without being joined by the anterior abdominal vein, which therefore had no communication whatever with the liver.

The musculo-cutaneous branch of the left subclavian appeared abnormally large, and the branch which enters the muscular body wall was traced down and found to be a continuation of the large abnormal parietal. This vessel ran between the obliquus externis and obliquus internis muscle of the body wall. Apparently some of the blood via the pelvics and anterior abdominal entered the left parietal and flowed through it to the musculo-cutaneous, and so on into the left anterior vena cava and sinus venosus.

The abnormal connection of the left parietal and musculo-cutaneous vein may be readily explained on the presumption that during the early development the capillaries of these vessels which


Left Anterior Vena Cava
External Jugular
Internal Jugular
Subscapula
Subclavian
Musculo-cutaneous
Obliquus externus
Obliquus internus
Parietal Vein
Pelvic Vein
Anterior Abdominal

normally arise from the same region came into communication with each other, so opening the path for the blood to flow from the pelvics into the anterior vena cava instead of into the liver. The large size of this parieto-musculo-cutaneous vessel, and the small size of the anterior abdominal vein were apparently determined by the same cause as that which deflected the anterior abdominal vein from its usual entrance into the liver to its abnormal entrance into the anterior vena cava, but what that was cannot be suggested.

END OF VOLUME XXX., PART I.

[PUBLISHED SEPTEMBER, 1917]

[Proc. Roy. Soc. Victoria, 30 (N.S.), Pt. II., 1918].

Art. VIII.—*The Physiography of the Glenelg River.*

By CHARLES FENNER, D.Sc.

(With Plate XIX.)

[Read 13th September, 1917].

I.—Introduction.

These notes were prepared in connection with the University Survey Camp, conducted in this area under Professor Skeats during the vacation of January, 1914. They are published with the permission of the Geological Survey of Victoria, under whose auspices this survey camp was arranged.

The Glenelg River is one of the largest and most important of Victorian streams. It is situated in the south-western corner of Victoria, and drains an area of about 4200 square miles. Major Mitchell, who discovered and named the river on July 31st, 1836, records that the native name was Temiángandgeen, "a name unfortunately too long to be introduced into maps."[1]

1 Major Mitchell's Journal, vol. ii., p. 212.

Both the Glenelg and its chief tributary, the Wannon, rise in the bold meridional sandstone ranges of the Grampians, and drain nearly all the Victorian territory west and south thence to the sea, emptying into Discovery Bay. When nearing the coast the river makes a long westerly sweep, looping across the border into South Australia, thence it doubles back round a coastal border hill, Mt. Ruskin, and enters the sea on the Victorian coast.

A casual examination of the river basin (see Plate XIX.) shows it to be curiously one-sided, and detailed enquiry into its physiographic history brings out many interesting details of the changes which have occurred during its lifetime.

It is very interesting to note the first impressions gained by that talented explorer and keen observer, Major Mitchell, in his traverse of this area. In the latter part of July, 1836, his expedition had reached the very flat land (average elevation, 530 ft.), which lies immediately north of the Glenelg basin. Here, since it was winter and very wet, he had great difficulties in getting his bullocks, waggons, etc., over the soft, swampy, sodden ground. After floundering on through lakes and swamps for many days, ever seeking solid ground, he made this entry on July 30: "By pursuing a course towards the base of the friendly mountains,[1] I hoped that we should at length intercept some stream, channel, or valley, where we might find a drier soil, and so escape from the region of lakes. . . . From here the pinnacled summits of the Victoria range presented an outline of the grandest character. The noble coronet of rocks was indeed a cheering object to us after having been so long half-immersed in mud. . . . I found at length, to my great delight, . . . a valley, where we finally encamped on a fine stream[2] flowing to the south-west over granite rocks (white felspar, quartz and silvery mica). . . . We had solid granite beneath us; and, instead of a level horizon, the finely rounded points of ground presented by the sides of a valley thinly wooded and thickly covered with grass. This transition, from all we sought to avoid to all we could desire in the character of the country, was so agreeable, that I can record that evening as one of the happiest of my life."

It was on the next day, July 31, that Mitchell actually discovered the Glenelg. (See Fig. 1.) Although he shows in all his records a keen instinctive knowledge for physiographic features, the peculiar nature of the course of this river for many days presented a com-

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1 The Grampians.

2 Probably Reilly's Creek.

plete puzzle to him. Of his first contact with the river he writes: "We now moved merrily over hill and dale, but were soon, however, brought to a full stop by a fine river flowing, at the point where we met it, nearly south-west. The banks were thickly overhung with bushes of the mimosa, festooned in a very picturesque manner with the wild vine. The river was everywhere deep and full, . . . on an average 120 feet wide and 12 feet deep. Granite protruded in some places, but in general the bold features of the valley through which this stream flowed were beautifully smooth and swelling. . . . A little rill then murmured through each ravine,

"'Whose scattered streams from granite basins burst,
Leap into life, and sparkling woo your thirst.'

It seemed that the land was everywhere alike good, alike beautiful."

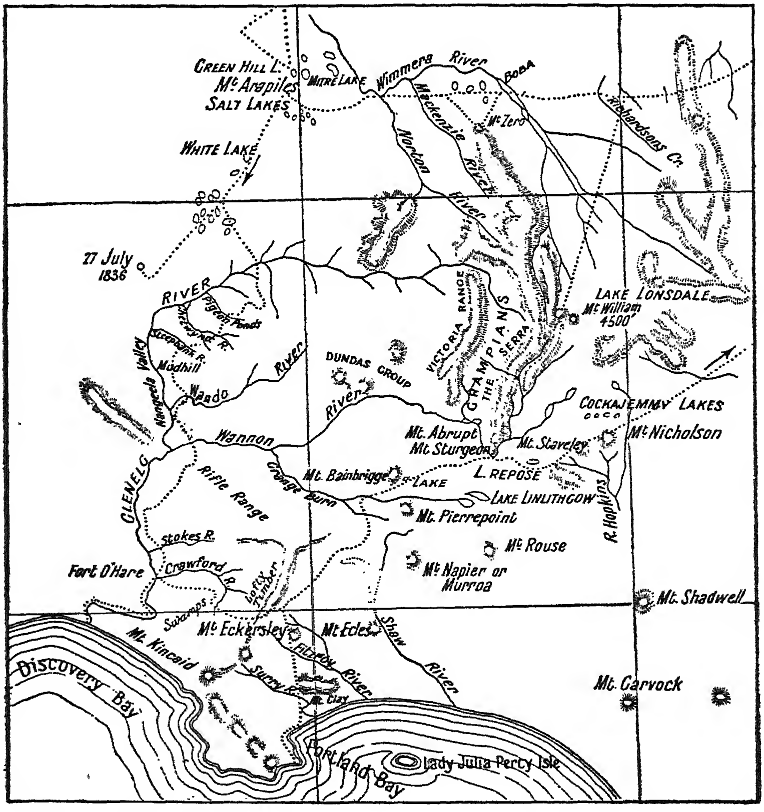


Fig. 1.—Map of the Glenelg Basin, as prepared by Major Mitchell in 1836. The spelling, heights, &c., are as given by Mitchell. His route, with dates, is shown.

II.—General Description of the Area.

The accompanying plan (Plate XIX.) shows the courses of the main stream, and its most important tributaries; the extent of the basin is shown by a dotted line, and the approximate contours of the area are also shown. Fig. 1 is copied from Mitchell's first map of the river and its tributaries, and shows the route of his expedition.

As has been previously noted, there is a distinct preponderance of tributaries to the east, and especially to the north-east. Indeed, except for a few short valleys, there are no tributaries on the western side at all. In order to more systematically consider the various features, we may conveniently divide the area into four parts; these are numbered respectively, A, B, C, and D in Plate XIX.

The chief distinctions between these four divisions consist in the nature of the drainage, but there are other characteristics which may be briefly summarised as follows:—

A.—The tract between the Glenelg and the South Australian border; low land, sloping gently to west and south-west. Irregularly timbered, mostly scrubby; poorly drained, abounding in swamps and lakes with low separating ridges, often of limestone; some dairying and grazing, sparsely populated. Recent work shows good agricultural possibilities in this area where extensive drainage schemes are undertaken.

B.—The tract north of the Glenelg, towards Goroke and Natimuk; slightly better populated, and with a better class of land, grazing, some wine and wheat; timber mostly scrubby, but abundant good redgum; badly drained, abounding in lakes and swamps, and with a few wandering "creeks."

C.—The tract enclosed by the Upper Glenelg and the Wannon; of varied elevation, rising in the Dundas highlands to 1535 feet; well drained by streams flowing north, north-west, and south; well peopled for the most part; good land, in places excellent, especially in the open downs to the south. The underlying rocks of this important area consist of a series of ancient gneisses, schists, slates, cherts, with acid and basic igneous intrusives. The most elevated portions (Grampians, Dundas, etc.) consist of lower carboniferous sediments—purple and grey sandstones and quartzites, strongly faulted; in the lower part of area C, calcareous jurassic mudstones occur; practically the whole area, up to 1000 feet, has been covered by marine deposits of late tertiary (? pliocene) age.

D.—The south-eastern part of the basin, extending towards Portland; lower land than C, but somewhat diversified; in the north excellent land as at Merino, etc., when the level-bedded jurassic mudstones occur; further south heavily timbered, but with big areas of "heath country." Open basalt plains cover about one-third of the area, the remainder consisting of level-bedded ferruginous and calcareous marine tertiaries (? pliocene, etc.); a few streams draining west and north-west.

III.—Rainfall.

The rainfall of the whole area is good, being a little above the average for the State. As will be seen, the distinctive nature of the topography and drainage in the four areas A, B, C, D, does not appear to be at all due to the rainfall, but rather a product of three factors: (a) elevation, (b) slope, (c) nature of the rocks. Mr. H. A. Hunt, the Commonwealth meteorologist, has courteously supplied the following details of the rainfall, based on 10 years' records. It will be noted that the only appreciable distinction is that the flat plains of area B, stretching from Apsley to Toolondo, suffer to the extent of five inches per annum, the rain-bearing winds having parted with a good deal of their moisture before this area is reached.

Annual Averages for Ten Years.

Area A.		Area B.	
Dartmoor	32.89 ins.	Apsley	25.10 ins.
Dergholm	26.86	Edenhope	25.82
Nangeela	26.92	Pine Hills	22.43
Poolaijelo	28.26	Charam	22.16
Strathdownie	27.48	Douglas	19.42
		Telangatuk	24.04
Av.	28.48	Av.	23.16

Area C.		Area D.	
Balmoral	24.81 ins.	Portland	33.54 ins.
Carapook	25.54	Branxholme	24.04
Roseneath	27.55	Condah	28.18
Coleraine	24.46	Croxton E.	27.57
Tulse Hill	29.77	Dunkeld	29.69
Melville Park	29.51	Hamilton	28.00
Montajup	26.36	Merino	29.83
Mooralla	29.26		
Av	27.16	Av.	28.69

IV.—Mountains and Hills.

As stated in the last section, differences of general elevation appear to have played a large part in producing the diverse features of the four divisions. Generally speaking, we may sum these differences up as follows (see Plate XIX.) :—

A.—Low, flat, gently sloping south-west; average elevation 2-300 feet, rises to 400.

B.—Higher land, fairly level, difficult to detect any general direction of slope, but probably slopes to north and west; average elevation 4-500 feet.

C.—Comparatively high lands, average 7-900 feet, rises in the western part to 1500 feet, and in the east to 3000 feet and over; deeply dissected by streams flowing in all directions from a central east-west ridge.

D.—Somewhat similar in elevation to area B, but with much more diversity of hill and valley; variety also introduced by volcanic hills and flows.

Apart from these considerations of elevation, the chief cause of the present disposition of the Glenelg and its tributaries lies in the manner of their growth. The basin of this stream, although itself of comparatively recent origin, appears to have still more recently, added greatly to its territory in two ways :—

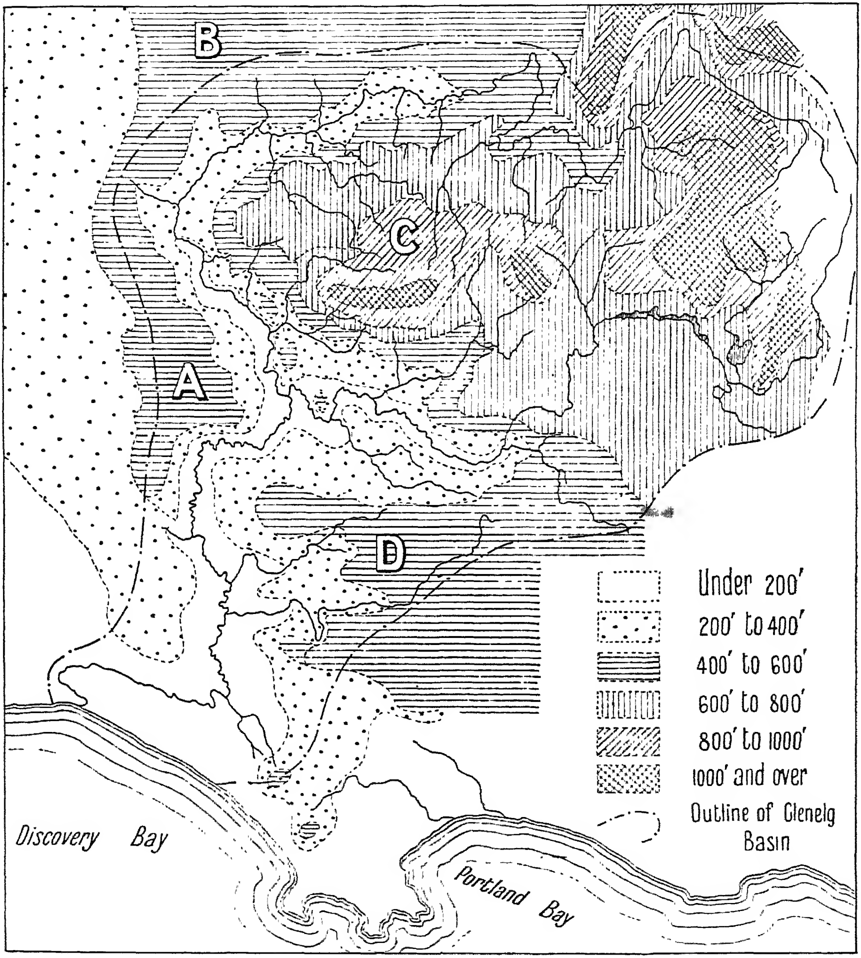
(i.) Aggressively, by the capture of less fortunately situated streams.

(ii.) Passively, by the diversion of neighbouring streams into the Glenelg basin on account of lava flows.

These possibilities will be dealt with more fully in a later section. Meanwhile, having accomplished a general survey of the whole area, we may deal with hill and valley in somewhat more detail.

(a) Grampians and Dundas Highands.—In these mountains most of the streams in the basin have their origins. They form the outstanding mountain feature of western Victoria, and consist of upper palaeozoic indurated sandstones and quartzites, block-faulted, with faults roughly north and south, the scarps facing east and the dip slope to the west. The Grampians were discovered and named by Mitchell, who in 1836 ascended the highest peak, Mount William (3827 ft.), and spent a freezing night on its summit. Mount Dundas (1535 ft.) is the extreme western member of the group.

(b) Continuation of the "Main Divide."—One point is worthy of discussion here since it bears on the question of the Main Divide



Map of the Glenelg River basin, showing the approximate relief of the area. In the high area below the letter C (over 1,000 feet), Mount Dundas rises to a height of 1,535 feet. In the Grampians area, in the north-east, where the shading also shows "over 1,000 feet," the ranges average about 2,000 feet (Mount William, 3,827 feet).

of Victoria. Evidence is gradually being accumulated which appears to show that this, our chief watershed, although of very great diversity in material, has yet a unity of structure. This general structure is of the "block-fault type," and in this the Grampians, Serra, Victoria, Black, and Dundas ranges are distinct partakers (if not the suggesters of the idea).[1]

A writer on the Geography of Australia[2] says: "The Pyrenees may be considered as the end of the Great Dividing Range on the continent." This, of course, suggests that the Pyrenees are also the end of the Main Divide of Victoria. Further, the much-debated uniform hachure line which marks the Divide on most maps of our State usually ends about Ararat.

As a matter of fact, this Divide, regarded as a structural feature of Victoria, does not end until the Glenelg is reached, less than 40 miles from the western border (see accompanying plate). The unity of structure hitherto referred to must cause the inclusion of the Grampians in the Divide, as also does the fact of the division of the north and south flowing drainage (see Fig. 2). The low gap at Ararat, where the head waters of the Mount William creek (northern) and the River Hopkins (southern) are almost without any separating elevation does not militate against this, nor does the similar gap west of the Victoria Range. Mr. T .S. Hart, who has given many years of careful study to the western highlands of Victoria, has shown them to consist throughout of a series of north-south ranges, with intervening north-south valleys.[3]

The railway departments of Victoria and South Australia have kindly provided sufficient reliable data of heights to allow of the construction of sections from north to south throughout the area here dealt with, and these clearly indicate the continuation of the Main Divide right to the Glenelg. There it gently plunges below the tertiary plains of the Murray estuary.

(c) Minor Elevations.—Hills which would come under this head are abundant and of great variety :—

(i.) Low-rounded hills, wholly of coast plain material, such as Mount Clay and Mount Kincaid, are residuals. The timbered ranges throughout area D are mostly of this type.

(ii.) Numerous hills in the Casterton-Wando Vale area are of soft jurassic mudstones capped by a level layer of ferruginous tertiary

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1 See T. S. Hart. "Highlands and Main Divide of Western Victoria," Proc. Roy. Soc. Victoria, December 1907, p. 270, line 36.

2 Commonwealth Year Book, No. 3. 1910.

3 B.A.A.S., Melb., 1914. "The Central Highlands and Main Divide of Victoria." T. S. Hart.

material. Robin Hill, near Corea Creek, with its flat top, may be cited as characteristic of this class.

(iii.) Around Casterton, Coleraine, and Merino, we find beautifully undulating, well-grassed country, the low rounded hills bearing witness to the evenness and softness of the level-bedded jurassic mudstones in which the streams have done their work. In places where the slopes are steeper, landslips are characteristic features; their abundance is probably due to the "greasy" nature of these felspathic mudstones, combined with their porosity. On a small scale interesting complications in the drainage of these hills have been caused by the landslips. The general fertile appearance of this part of the country greatly impressed Mitchell, and on his suggestion the Hentys in 1837, brought stock up from Portland, settling in the neighbourhood of the present township of Henty. In his pamphlet on "The First Settlers in Victoria," Henry Henty says of this venture: "When they caught sight of the country, 'Why, here is Sussex!' they exclaimed, 'Sussex without a building, Sussex without inhabitants, Sussex all our own.' They galloped their horses for joy, cheering and throwing up their hats."

(iv.) In area A, long low ridges, generally trending north-west, run away into South Australia. In these limestone often plays a large part, and caves are frequent.

(v.) Granite hills occur rarely, Bracken Hill is an example. Most of these hills are residuals, the ancient, resistant bed-rock (granites, gneisses, slates, etc.), having been deeply dissected in places by the Glenelg and its tributaries; other hills of this class are very ancient physiographic features, relics of a prior peneplanation, covered by lake and marine deposits, and more recently uncovered by stream action. The Hummocks, near Bracken Hill, will be dealt with more fully at a later stage. Volcanic hills, e.g., Mount Bainbrigge and Mount Eckersley, occur, mostly in the south-east.

V.—Valleys and Streams.

(a) Glenelg River.—The valley of the Glenelg lies almost wholly in those rocks of coastal plain origin, which are uniformly coloured sage-green on our geological maps. Accepting all these beds as of one age, and as Pliocene, we see that the development of the river must be still more recent, and we thus have a freedom from any effects of complicatory prior drainage-systems, such as must be considered in dealing with most other Victorian rivers.

Mr. T. S. Hart[1] believes the Main Divide of Victoria to have been slowly uplifted along an east-west line, with trough faults on either side. This elevation amounts to some 6000 feet in the extreme east, and becomes gradually less westward, so that it seems most likely that in the area under consideration we have the last traces of this great hoist as it gradually decreased to nothingness. To the south, at Portland, a proved depth of 2265 feet[2] of tertiary sediments indicates a very great subsidence there.

If we picture the whole of the old Murray estuary as slowly rising above sea-level, it is evident that the first part uncovered by the sea would be the Dundas Highlands—our area C. We should then have developed there the two sets of short consequent streams that still exist (see map). One set, Chetwynd, Pigeon Ponds, Mathers' creeks, etc., flowing north, and the other set, Dundas, Steep Bank, Wando, Koonong Wootong, etc., more or less southerly. A certain amount of capture in the region of their headwaters has slightly but not materially affected these streams since then. (See Fig. 2.)

The remaining flatter part of the estuary floor would probably rise a little more slowly, the sea apparently receding along a north-west south-east coastline. Such a movement appears to be still continuing, probably with minor oscillations, and is aided in its reclamation work by the ridges and sand-dunes built by winds and currents. The north-north-west trend of the parallel ridges and swamps in that corner of South Australia is strongly suggestive of this, and the part played by coastal dunes during the uprising is evidenced by the occurrence, all through the areas concerned, of patches of dune sand, sometimes very extensive, at other times blown away and re-collected in recent hollows. With the continued recession of the sea, the northern streams would endeavour to make their way north, probably a little west; while the southern streams would gather to form two or three more or less uniformly south flowing streams (see Fig. 2). Of these, the Glenelg would be one, and a stream formed by the union of the Dwyer's Main Creek, and the Upper Wannon would almost certainly be another.

The sad lack of grade to the north would act against any definite valleys being cut out and adhered to there, and we should probably have our northern streams degenerating into chains of shallow lakes, such as still occur in area B. The sister stream, the Wim-

1 Proc. Roy. Soc. Victoria, December, 1907, and B.A.A.S., 1914.

2 Quoted by H. Herman, Vict. Handbook, B.A.A.S., 1914, from Vict. boring records.

mera, having a bigger body of water, has made an heroic but unsuccessful effort to persist in flowing on to reach the Murray in the north.

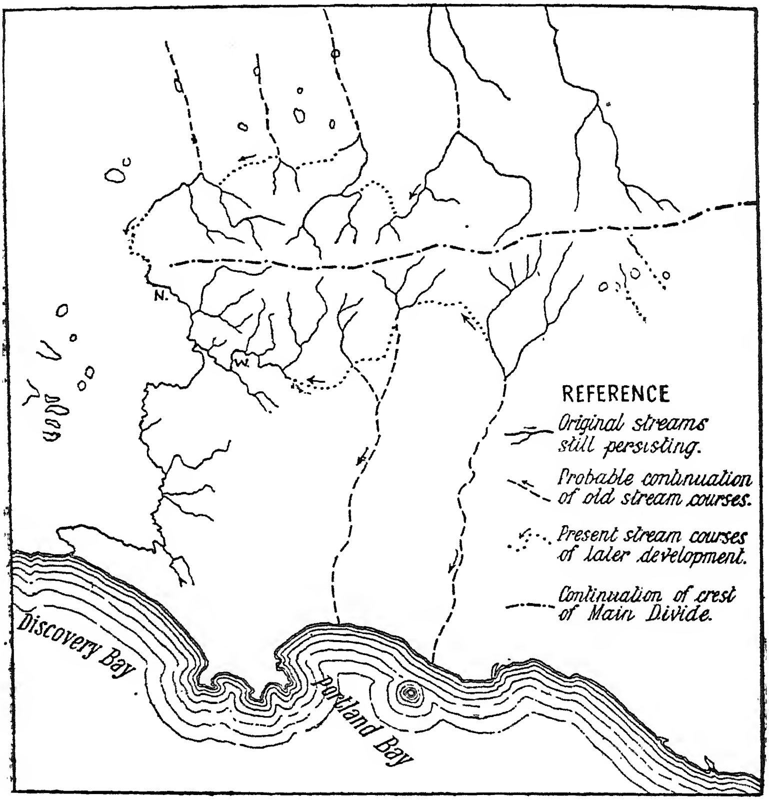

Fig. 2.—Diagram to indicate the mode of origin of the present drainage system of the Glenelg, as it is conceived to have taken place. The old stream courses to the north, shown by broken lines, probably never firmly established themselves, owing to the lack of grade; while those shown to the southward have been covered by the "newer basalt" flows.

The southern streams were more blessed, and of these fortune seems to have favoured the Glenelg. With a good slope, soft rocks, and a good supply of water, this stream would rapidly deepen its valley, receiving few tributaries en route. Nearly all that were developed naturally came from the east, because the gentle tilt of the land surface to the south-west would tend to direct the western water away from the river, to collect in swamps and lakes, as is still the case.

As the land rose the Glenelg would continue to deepen its valley and increase its territory. In the soft jurassic rocks the valley is wide, and flood-plains, cut-offs, and terraces are to be seen; but in the somewhat harder, level-bedded limestones lower down the course, below Dartmoor, the river has cut down into a steep valley with high precipitous cliffs that still persist.

At this time we may picture two chief tributaries of the Glenelg—an eastern one, the Wannon (W. Fig. 2), and a more northern, to which we may give Mitchell's name—the Nangeela valley (N. Fig. 2). The Nangeela would have everything in its favour to proceed with vigorous headward erosion, and we may picture it advancing more and more to the north, rounding the Dundas highlands, and ultimately, one by one, capturing the struggling northward streams, eventually reaching back into the territory of the Wimmera itself, as indicated in Fig. 2.

In August, 1836, Mitchell[1] made the following observations regarding the flow of the river at a point about four miles north of the junction with the Stokes River:—Average breadth, 35 yds.; mean depth, 17 ft.; velocity of current, 1863 yds per hour. This represents a flow of about 62,000,000 gallons per hour. The river is subject to very severe floods, when, of course, the flow is even greater. On the other hand, in summer time, the surface flow often practically ceases. This was the case at the time of our camp there in January, 1914.

The absence of any deep, wide estuary at the mouth of the Glenelg was a great disappointment to Mitchell. The mouth is shallow, and shoaled with shifting sand bars. On August 20, 1836, Mitchell wrote in his journal: "The day was squally, with rain, nevertheless, during an interval of sunshine I obtained the sun's meridian altitude, making the latitude 38° 2′ 58″ S. I also completed, by 2 p.m., my survey of the mouth of the river and the surrounding country. . . . On re-entering the river from the sea, I presented the men with a bottle of whisky, with which it was formally named the Glenelg, after the present Secretary of State for the Colonies."

(b) The Wannon.—This tributary, whose native name has fortunately been preserved by Mitchell, was favourably placed in the soft jurassic and tertiary rocks. There are, however, two or three features in the present Wannon valley that demand explanation. The valley may be divided into three very distinct tracts. In the lower Wannon, from Tahara to Casterton, we have a fine stream,

1 Journal, vol. ii., p. 218.

winding in a definite channel through a wide, middle-aged valley (see Plate XIX.). In the central tract of the Wannon, up as far as Mount Sturgeon, we have the river taking a most unexpected loop to the north, towards the mountains, and thence wandering sluggishly and wide, with practically no defined valley, north-west, then west, and south-west, passing over waterfalls into the lower Wannon in the neighbourhood of Tahara. Still further towards the source we have Dwyer's Main Creek and the Upper Wannon (above Mt. Sturgeon) flowing almost due south in deep stable valleys in the hard rocks of the Grampians.

We thus have an upper and a lower tract of more mature age, with a central part of extreme youth. As before indicated, there appears to be no doubt that this uppermost part, with Dwyer's Main Creek, originally flowed on to the south as a separate river; also that the lower Wannon did not extend nearly so far eastward as at present (see Fig. 3). With the advent of the newer basalt period, however, a great sheet of lava effectually dammed up these present tributaries of the Upper Wannon, in the neighbourhood of Mt. Sturgeon, and forced the streams to slowly find their swampy way right round the northern margin of the basalt sheet, finally reaching the wider and more mature valley of the lower Wannon. Thus, to use the terminology of rivers, the Lower Wannon is a "consequent" stream, the extreme Upper Wannon is a "captured consequent," while the central part may be called an "insequent" stream (a term used by Andrews, "Physical Geography of N.S.W.," p. 36).

The deeper valley of the Lower Wannon is now endeavouring by means of headward erosion, as at the Wannon and Nigretta falls, to reduce the three parts of the stream to a more harmonious grade. The events are so recent, and the evidence so clear, that any geological map of Victoria will evidence the truth of this theory; especially is this so if taken in conjunction with the more detailed county maps as to the nature and direction of the river's course.

It should be noted also that of the two older tracts of the Wannon, the lower one—from Tahara to Casterton—is wholly due to erosion. The upper part, within the Grampians, lies in valleys that are probably of tectonic origin, and older than the Tahara-Casterton portion.

(c) Wando and Wando Vale Ponds:—These two streams rise in the western part of the Dundas highlands, and flow south-westerly,

converging towards the Hummocks. Passing through the latter hill in two narrow gorges, they junction, and flow into the Glenelg near the "Retreat" homestead. Since the work done by the survey party was largely in their basins, they were more closely

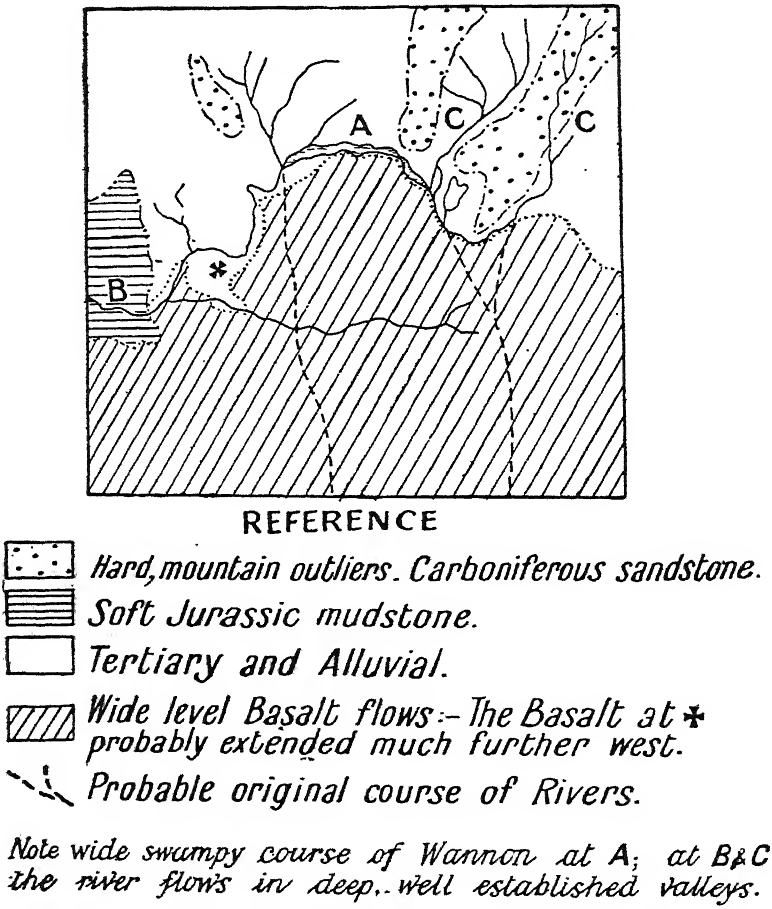

Fig. 3.—Geological plan to illustrate more clearly the effect of the lava sheet in determining the present course of the Wannon. The carboniferous sandstones are here referred to as "outliers," in respect to the very ancient underlying bed-rock, which is covered by a thin layer of marine tertiary and recent alluvial material.

observed than other similar tributaries of the Glenelg. The name Wándo was given by Mitchell, who appears to have elicited it from an aboriginal female whom he interrogated there. The

course of these streams was decided by and set out on the sloping coastal plain. When their valleys were once selected, they would soon carve through the lose, level-bedded tertiary sediments, and then cut down into the soft, decomposed jurassic mudstones. Under such conditions very wide, open U-shaped valleys are found.

Underlying these last-mentioned sediments, and in some cases immediately below the tertiaries, very hard gneisses and granites were met, with the result that narrow, fairly steep-sided gorges

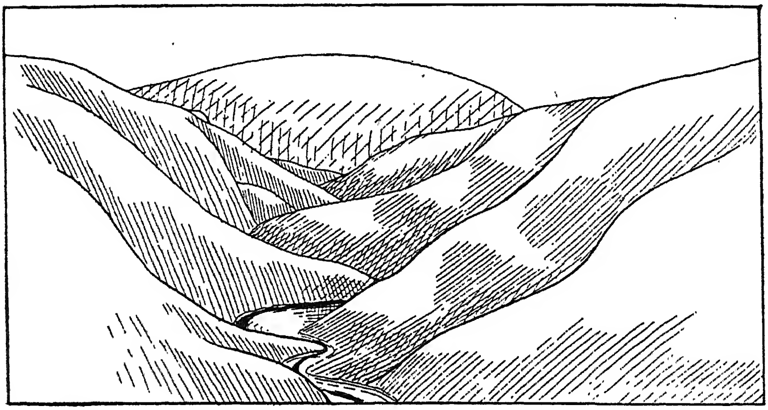

Fig. 4.—Sketch of gorge cut by Robertson's Creek into the hard schists and gneisses which underlie the thin capping of level-bedded marine tertiaries.

mark the places where such superimposition occurred. Good examples of such gorges are those of the Wando and Robertson's Creek (Fig. 4), that of Corea Creek is much more precipitous; they provide patches of rugged and interesting scenery, quite a break in the monotony of the level uplands into which they are cut.

In the lower Wando and Wando Vale Ponds the course of the stream, with its numerous large waterholes, has within recent years quite silted up; probably this is mainly due to the opening up of the hillside lands by agriculture. In summer the streams cease to flow, but good water for stock may always be procured by scooping out a hole in the sands of the creek bed.

(d) The Upper Glenelg and "Brim Spring Gap."—The uppermost parts of the Glenelg show a tortuous course. The stream rises in the heart of the Grampians, at the "Chimney Gap," just over the ridge from one of the south-flowing tributaries of the Wannon. It then flows north-east 12 miles, north-west 18 miles,

and then south-southeast about 18 miles, forming a V-shaped loop with the sharp angle to the north. This angle is at a point east of the Black Range, near Brim Spring. A low gap occurs, and it is interesting to know that some years ago a scheme was proposed whereby a canal was to be dug to carry the water from the upper Glenelg across to the Wimmera on the north. While not able to visit the spot, the writer has obtained much valuable information from the details of the railway survey through the gap, and also from Miss Sinclair, of the Brim Spring school. There appears to be evidence that the upper Glenelg originally flowed north, perhaps down Norton's Creek, to the Wimmera. This area is well worth closer investigation.

(e) Minor Streams.—A number of other streams present peculiarities in their courses, and leave much room for detailed physiographic work. Of these may be mentioned the Pigeon Ponds, Steep Bank rivulet, Harvester Creek, and the Stokes River; the latter shows a remarkably sharp southern loop north of the township of Lyons, probably due to the lava stream having filled up part of its former valley.

VI.—Lakes.

The basin of the Glenelg has an extremely ill-defined boundary. Except in the case of the Grampian district, low, flat, swampy divides are the rule. On the eastern side this low divide has been carefully selected as the route for the Dunkeld-Portland portion of the railway; lakes and swamps, lying on the basalt sheet, are common here. To the north, in area B, the very numerous lakes are perhaps to some extent relics of the streams which attempted to make their way northwards before being captured by the active headward erosion of the Glenelg; there are no streams whatever adjacent to the Glenelg valley here. In the north-west one or two ill-defined creeks occur, such as the Mosquito creek, towards Apsley. To the west of the Glenelg, if we except a few minor streamlets, there are no tributaries whatever; the water collects in the depressions, and is got rid of by evaporation and percolation. Most of these swamps, especially across the border, are elongated along north-north-west axes. Woods[1] records that at flood times the Dismal Swamp—a large swamp north of Mount Gambier—drains eastward into the Glenelg.

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1 Geological Observations in South Australia. J. E. Woods, 1862.

The lakes may be roughly classified as (i.) solution lakes, (ii.) cut-offs, (iii.) basalt dammed, and (iv.) those on basalt sheet.

(i) Solution Lakes.—This type, dealt with by Professor Gregory,[2] is common. Mitchell had close experience with a large number, and deals with them in some detail. Undoubtedly wind erosion plays a large part in forming many of these lakes, as shown by the frequently occurring crescentic bank of sand on the eastern shores. A beautiful drawing of the group called the Greenhill lakes is given by Mitchell in Vol. II. of his journal, plate XXXII.

(ii) Cut-offs. As before mentioned, these occur in the wider and more mature portions of the Wannon and Glenelg, especially where jurassic mudstones are dominant.

(iii.) Swamps and lakes caused by the damming up of streams by lava flows are common northward from Glenthompson towards Mount William. These include the Cockajemmy lakes. Larger ones occur west of Mount Abrupt.

(iv.) The lakes found on the basalt sheet itself are numerous and shallow. They are similar to those found all over south-western Victoria, and bear witness to the immaturity of the drainage systems. They are usually ascribed to one or more of the following agencies:—Sagging of the basalt, the meeting of two or more lava flows, wind erosion, and more rarely, crater depressions.

VII.—The Hummocks.

This remarkable natural feature deserves a special section for itself. It consists of a hill, a little over 450 feet high, cut through by two steep-sided gorges—those of the Wando and the Wando Vale ponds. An observer coming eastwards up the wide, open valley of the Wando, cannot fail to be struck by the fact that this hill lies right across the valley almost at right angles to the course of the stream. Closer observation is necessary to show that it is cut through by the two streams named, which narrow their valleys down to gorges a chain or less in width. A detailed survey of the immediate area was made under the direction of Mr. O. A. L. Whitelaw, Field Geologist, Geological Survey of Victoria, and is shown in Figure 5.

To the traveller along the Harrow road to the east, a similar puzzle is presented of two wide U-shaped valleys suddenly narrowed to two small V-shaped guts. Since it lies on Major Mitchell's

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2 Geography of Victoria, pp. 132 *et seq.*

route, we may be sure so keen an observer would not pass it without remark. He records that the native name of the hill now known as the "Hummocks," was Kingànyu, and adds: "Proceeding along the valley, the stream on our left (the Wando) vanished at an isolated rocky hill; but, on closer examination, I found the

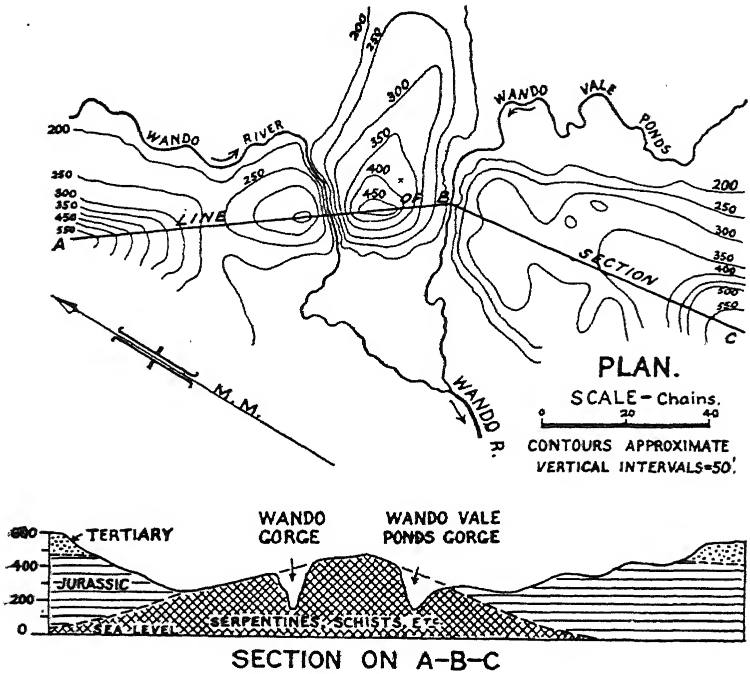

Fig. 5.—Plan and section of "The Hummocks." The contours are from data collected by Mr. P. B. Nye. The plan shows clearly the wide valleys carved out by the two streams in the softer rocks both above and below the "gorges."

apparent barrier cleft in two, and that the water passed through, roaring over rocks. This was rather a singular feature in an open valley, where the ground on each side was almost as low as the rocky bed of the stream itself. The hill was composed of granular felspar, in a state of decomposition.[1] It is not so easy to suppose that the river could ever have watered the valley in its present state, and forced its way since through that isolated hill of hard rock, as to suppose that the rock now isolated originally contained

1 It is largely serpentine, with talc schists, quartz schists, phyllites, etc.

a chasm, and afforded once the lowest channel for the water, before the valley now so open had been scooped out on either side by gradual decomposition." When reading this interesting explanation we must remember that it was written in 1836.

The Hummocks have received a fair amount of attention from geologists. They were visited about 1886 by F. L. Krause, who figured them in the Mines Department report of that year. Strangely enough, he did not visit the second gorge, that of the Wando Vale Ponds, and refers to it as a "road cutting." It is evident that the Wando and the Wando Vale are at this point "superimposed streams," with wonderfully clear and convincing characteristics.

When the streams commenced their downward cutting, they were in soft tertiary material; the ridge of resistant rock lay hidden less than 200 feet felow, and almost at right angles to their course. With the gradual deepening of their valleys, this hard ridge was encountered, and there was nothing left to do but to "go on with the work"; the two V-shaped gorges are the result. The great contrast between the very hard rock of the Hummocks, and the very easily eroded jurassic and tertiary material under which it was hidden, have given this feature much greater distinction and interest (see Fig. 5).

General Conclusions.

Of much interest in this area are the traces found of ancient physiographic features, preserved by burial under sediments of various ages and subsequently exposed by stream action. Of those that were investigated in the field by the survey party, the oldest may be referred to as the pre-jurassic.

This ancient landscape has left many traces of its outlines, such as may be seen in the Wando Vale district. It was evidently a surface of low relief, with its ridges and valleys carved out in a series of ancient resistant rocks. The most northern part of the jurassic lake system, as far as it has been preserved, embraced this area, and the accumulating sediments of this lake gradually covered the submerged landscape.

Thus it was in part preserved until comparatively recent times. Of these ridges, now partly exposed, but still with jurassics overlapping their flanks, we may mention Cashmere Hill, Bracken Hill, and the ancient tablelands exposed in the Robertson's Creek and Wando gorges. Clearest of all, however, in the Hummocks (Fig. 5),

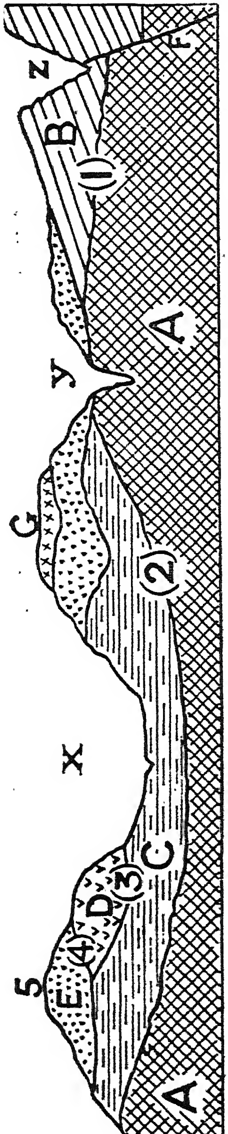

Fig. 6.—Diagrammatic section (composite) to show (a) the relationships of the various rock types to one another, (b) the various "erosion periods" of which records are found in the area and (c) the general characteristics of the present valleys and hills in the Glenelg River basin. A detailed account of this section (with references to the letters and figures) will be found in the context.

so venerable a feature that it can only be regarded with awe. Except for the two gorges, it stands to-day in all likelihood with the same general outline that it presented to the sun and wind when it formed part of the landscape of those extremely remote mesozoic ages.

Figure 6 represents in a diagrammatic way the chief features of importance that have been referred to in this paper. The various letters and figures of that diagram are explained below, and will serve as a general recapitulation.

(*a*) *Rock Types.*

A.—The bedrock of the area, outcropping abundantly in the northern parts, and greatly influencing the physiographic features (see A. Fig. 6). As far as known it is non-fossiliferous; it consists of mica schists, talc schists, phyllites, slates, etc., intruded by both acid and basic plutonics and dykes. Many ages of rocks are perhaps represented in this complex, but the youngest present may be taken as not younger than ordovician. These rocks are on the whole very resistant to weathering and erosion.

B.—The faulted and tilted sediments of the Grampians and Mt. Dundas (probably Lower Carboniferous); grey and purple mudstones, sandstones, and quartzites. These are strongly resistant to erosion, and form the highest land in Western Victoria, comprising much magnificent mountain scenery. The letter F in Fig. 6 indicates the faulting which is so prominent in these rocks.

C.—Jurassic lacustrine sediments, consisting of felspathic mudstones, sandstones, and occasional grits; frequently calcareous, and in places carbonaceous; nearly always level-bedded; weather easily and good outcrops are rare. Fine agricultural land, wide valleys, broad, fertile flats, and rounded hills.

D.—Older Basalts, etc.—These are taken as belonging to various periods in the tertiary. Different types occur; the relics are small and scattered. They are of minor importance from the physiographic point of view.

E.—Tertiary limestones, gravels, and sandstones often strongly ferruginous. These are in places fossiliferous; very widespread, originally covering the whole of this area up to the thousand-foot contour line. They are level-bedded, and easily eroded. In the higher areas these beds are naturally quite thin—a few feet in thickness; the deposits become thicker towards the south and west; in the southern areas they reach a depth of from two to three

thousand feet. Some of the most famous tertiary fossil beds in Australia occur in this series in the Wannon and Glenelg valleys.

G.—The Newer Basalts.—These flows cover large areas in the south-eastern portion of the Glenelg Basin; wide level sheets with occasional cones. They have considerably influenced the physiography, obliterating the old valley systems, diverting streams, etc. The features so far developed on these areas are, of course, considerably more recent than those of the Glenelg Basin as a whole.

(*b*) *Valley Types.*

(w.).—As typified in the lower Wando River; broad and gently-sloping in the tertiary and jurassic, narrow and steep-sided in the underlying bedrock (A). See Fig. 6.

(x.). As typified by the Lower Wannon; broad, gently-sloping valleys, with wide flats, almost wholly in tertiary and jurassic sediments.

(y.).—As typified by Robertson's and Corea creeks; valley in level coastal plain material, superimposed on hard ancient rocks (A); jurassic sediments absent.

(z.).—As typified by the Upper Wannon (Dwyer's Main Creek, etc.); deep V-shaped valleys, partly tectonic in origin.

(c) *The Past "Erosion Periods."*

We may regard the periods of rock-formation (sedimentation, etc.), as being "positive" periods in the geological history of the area. Equally important are the intervening "negative" periods —the periods of rock-destruction (erosion, etc.). These great erosive periods are represented only by the unconformable bounding lines between the rocks of any two ages, as shown in Figure 6.

(1) Post ? Lower-Palaeozoic and Pre-lower-carboniferous. — As already stated, this boundary was not investigated.

(2) Post ? Lower-palaeozoic and Pre-jurassic.—This erosion period ended in the formation of an area of low relief to which extended reference has already been made. Whether lower-? carboniferous rocks (B) ever covered the more ancient rocks (A) over the whole area cannot be determined.

(3) Post-jurassic and Pre-?older Basaltic.—Some valleys of this period are preserved by remnants of basaltic flows; such basalts are older than the tertiary (Murray gulf) material, and are here loosely included under the comprehensive term of "older basalts." While much theory could be indulged in regarding this erosion period,

from evidences in other areas, there is no evidence of any value so far available here.

(4) Post-?older Basaltic and Pre-Murray Gulf (tertiary).—Both the top and bottom limits of this erosion period are stated in terms that are unavoidably vague. The volcanics referred to may be of any age from jurassic on to about middle tertiary. The line marked 4, Fig. 6, represents in section that area of low relief that was gradually submerged, about the middle of the tertiary period, under the great "Murray Gulf."

(5) Following this last distinctly marked period of marine transgression and sedimentation (E), there came a period of uplift, with the restoration of the area as a land surface. This brings us once more to our tertiary coastal plain, the subsequent physiographic evolution of which has been the subject of this paper.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. IX.—*Some Australian String Figures.*

BY KATHLEEN HADDON

(Communicated by Sir W. Baldwin Spencer, K.C.M.G.; F.R.S.)

(With Plates XX.-XXIV.)

[Read 13th September, 1917].

In the summer of 1914, during the visit to Australia of the British Association for the Advancement of Science, a trip to Milang, from Adelaide, gave us the opportunity of seeing some aborigines. These natives were of the Krapingala tribe, from the shores of Lake Alexandrina, and although they have been in contact with white people for a long time, they still retain the memories of some of their old customs.

For many years now I have made a study of Native String Figures, of Cat's Cradles, from all over the world, and, as none have hitherto been described in detail from Australia, this seemed a good opportunity to collect all that there was time for. A large number of finished figures have, however, been described by Mr. Walter E. Roth,[1] some of which are the same as those that I have collected, but as he does not describe the method of formation, it is impossible to tell if they were arrived at in the same way.

Later on, in the same year, on the way back from British New Guinea, my father and I spent some time at Thursday Island, where we met his friend, Mr. Robert Bruce. With him were two "boys" from Cape York, and I was thus enabled to collect some more Cat's Cradles from the extreme north of Australia.

The figures all show a marked resemblance in technique to those found in Torres Straits and British New Guinea, and in many cases they are identical. It is difficult to generalise from such a small number, but comparison with Mr. Roth's plates gives the same results—namely, that more than half the figures represent men or animals, whilst the rest are common natural objects, or manufactured articles. Two of the moving ones represent "Making Fire" and a "Corroboree" respectively, but none have yet been collected that have any known connection with mythology or magic, nor have any songs been recorded, such as are common in Torres Straits and New Guinea.

1 Roth, W. E. *North Queensland Ethnography.* Bulletin No. 4, March, 1902.

With more material, however, these may be found, but it is imperative that any collecting should be done without loss of time, for the aborigines are fast dying out, and even now in many tribes these figures are only known to the old people.

The nomenclature[1] adopted was invented by Drs. Rivers and Haddon.[2]

A string passed over a digit is termed a loop. A loop consists of two strings. Anatomically, anything on the thumb side of the hand is called "radial," and anything on the little finger side is called "ulnar"; each loop, therefore, is composed of a radial and ulnar string. By employing the terms thumb, index, middle finger, ring finger, little finger, and right and left, it is possible to designate any one of the twenty strings that may extend between two hands.

A string lying across the front of the hand is a palmar string, and one lying across the back of the hand is a dorsal string.

Sometimes there are two loops on a digit, one of which is nearer the finger-tip than the other. Anatomically, that which is nearer to the point of attachment is "proximal," that which is nearer the free end is "distal." Thus, of two loops on a digit, the one which is nearer the hand is the proximal loop, that which is nearer the tip of the digit is the distal loop; similarly, we can speak of a proximal string and a distal string.

In all cases various parts of the string figures are transferred from one digit or sets of digits to another or others. This is done by inserting a digit (or digits) into certain loops of the figure, and then restoring the digit (or digits) back to the original position, so as to bring with it (or them) one string or both strings of the loop. In rare cases a string is taken up between thumb and index. A digit may be inserted into a loop from the proximal or distal side, and in passing to a given loop the digit may pass to the distal or proximal side of other loops. These expressions are used as a general rule instead of "over and under," "above and below," because the applicability of the latter terms depends on the way in which the figures are held. If the figures are held horizontally, "over and above" will correspond as a general rule to the distal side, while "under and below" will correspond to the proximal side. In some cases where there is no possibility of confusion, the simpler terminology is used.

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1 The following passages are taken from my book, "Cats' Cradles in Many Lands," by the courtesy of the publishers, Messrs. Longmans, Green & Co.

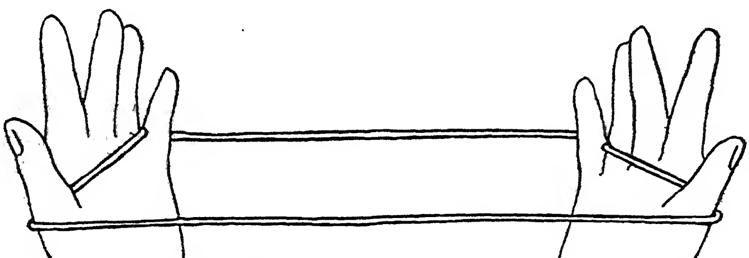
2 Rivers, W.H.R., and Haddon, A. C., "A Method of Recording String Figures and Tricks." *Man*, October, 1902, 109, p. 146.

A given string may be taken up by a digit so that it lies on the front or palmar aspect of the finger, or so that it lies on the back or dorsal aspect. In nearly all cases it will be found that when a string is taken up by inserting the digit into the distal side of a loop, the string will have been taken up by the palmar aspect of the digit, and that the insertion into the proximal side of the loop involves taking up the string by the dorsal aspect of the digit.

Other operations involved are those of transferring strings from one digit to another, and dropping the string from a given digit or digits.

The manipulation consists of a series of movements, after each of which the figure should be extended by drawing the hands apart and separating the digits. In some cases in which this would interfere with the formation of the figure, a special instruction will be given that the figure is not to be extended. Usually, it is advisable to retain the loops as near the tips of the digits as possible, and to keep the strings as loose as you can until the completion of the figure.

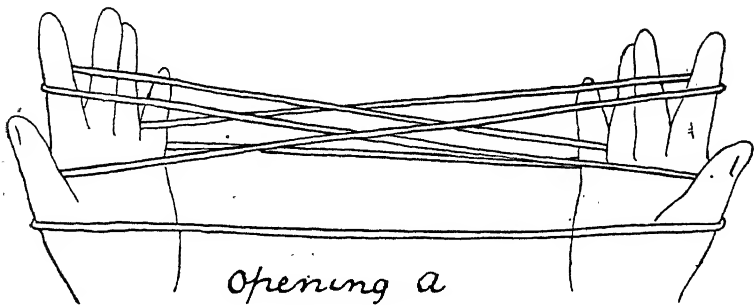
There are certain opening positions and movements which are common to many figures. To save trouble, these may receive conventional names; the use of these will soon be apparent.


Position I

Position 1.—This name may be applied to the position in which the string is placed on the hands when beginning the great majority of the figures.

Place the string over the thumbs and little fingers of both hands, so that on each hand the string passes round the back of the little finger, then between the little and ring fingers and across the palm; then between the index and thumb and round the back of the thumb to the radial side of the hand. When the hands are drawn apart the result is a single radial thumb string and a single ulnar little finger string on each hand, with a string lying across the palm.

This position differs from the opening position of the English cat's cradle, in which the string is wound round the hand so that one string lies across the palm and two across the back of the hand, with a single radial index string and a single ulnar little finger string.



Opening a

Opening A.—This name may be applied to the manipulation which forms the most frequent starting point of the various figures. Place strings on hands in *Position 1.* With the back of the index of the right hand, take up from the proximal side (or from below) the left palmar string and return. There will now be a loop on the right index, formed by strings passing from the radial side of the little finger and the ulnar side of thumb of the left hand, i.e., the radial little finger strings and the ulnar thumb strings respectively.

With the back of the index of the left hand, take up from the proximal side (or from below) the right palmar string and return, keeping the index within the righ index loop all the time, so that the strings now joining the loop on the left index lie within the right index loop.

The figure now consists of six loops, on the thumb, index, and little finger of each hand. The radial little finger string of each hand crosses in the centre of the figure to form the ulnar index string of the other hand, and similarly the ulnar thumb string of one hand crosses and becomes the radial index of the other hand.

The places where the strings cross in the centre of the figure may be termed the crosses of *Opening A.*

To "*Navaho.*"—When there are two loops on a digit, a distal one and a proximal one, to *Navaho* is to lift the proximal loop over the distal one and over the tip of the digit on to its palmar aspect.

"*Pindiki*" *is* a native name for the final extension of many of the figures. It consists of passing the index-fingers proximal to the ulnar thumb string, and bringing them up through the thumb loop

so that this string makes a half turn round their tips, at the same time keeping the thumbs closely pressed against the index fingers to hold the ulnar thumb string firm. Then extend the figure by turning the palms of the hands away from you.

You are sometimes required to twist a loop. This may be done "clockwise"—that is in the direction in which the hands of a clock travel—or in the opposite way, which is termed "counter clockwise."

In some finished figures, if the strings are pulled apart carelessly a hopeless tangle is the result. To avoid this, take the top and bottom straight strings of the figure and pull them apart, and the string will usually resolve itself into a simple loop.

The string selected should be smooth and pliable, and one which is not liable to kink. Macrami thread, or a fine woven cord, like blind cord, will be found to be very suitable. A length of about 6 ft. 6 in. (2 metres) is usually the most convenient. The ends should be tied in a reef knot, or sewn together with cotton, or, best of all, spliced.

1. (Plate XX.)—Barbed Spears = *Miral Kaiperi.* (South Australia).

Collected by Miss C. Herdman.

Hold the string between the thumb and index fingers, the hands being about six inches apart, and make a loop by bringing the right hand towards you and to the left. Hold the strings between the thumbs and index fingers, so that both the loops hang down, and pass both index fingers towards you through both loops.

Draw the hands apart, and turn the fingers up (Top Opening).

Pass the right thumb distal to the proximal radial index string, and pick up the proximal ulnar index string from the proximal side.

Pass the left thumb distal to the proximal index loop, and pick up the distal ulnar index string from the proximal side.

Pass the right little finger distal to the distal ulnar index string, and pick up the proximal radial index string from the proximal side.

Pass the left little finger distal to the proximal ulnar index string, and pick up the proximal radial index string from the proximal side.

Pass the middle fingers distal to the distal radial index string, and into the little finger loops distally, then straighten them out, thus picking up the distal ulnar index string.

Release the thumbs, pass them distal to their original loops, and pick up the distal radial index string beyond the point where it is crossed by the radial middle finger string.

Hook the little fingers over the ulnar middle finger strings, re-release the middle fingers, and pull down the little fingers to extend.

Release the thumbs and the little fingers and the spears are thrown.

The inverted triangle in the centre represents the barb.

2. (Plate XX.)—GRANITE ROCKS=*Tarkai.* (South Australia).

Opening A.

Pass the thumbs proximal to the index loops and into the little finger loops proximally. Pick up the radial little and ulnar index strings. Release the index fingers.

Pass the index fingers distally into the thumb loops, and out towards you proximal to the two distal strings, but distal to the proximal string (which runs straight across), turn the index fingers down and up away from you and pick up this string.

Keeping the thumbs pointing away from you, pass them proximal to the ulnar little finger string and pick this up through the thumb loops. Release little fingers.

Transfer the thumb loops to the hooks of the little fingers.

Keeping the little fingers hooked down, pass the thumbs distally through the little finger loops, and pick up the radial, little, and ulnar index strings. Release indices and Pindiki.

3. (Plate XX.)—A NIGHT OWL=*Kroldambi.* (South Australia).

Make the "Granite Rocks."

Hold the two thumb strings firmly against the base of the index finger, and release the little fingers.

Pass the little fingers proximally through the loops just released, and hold down the ulnar index string. Release the index fingers.

Pindiki the original little finger string.

This represents the Night Owl, with its large ears.

4. (Plate XXI.)—WATER RAT=*Ekeli.* (South Australia).

Hold part of the string with the thumbs and index fingers, the hands being about six inches apart. Make a small ring by passing the right hand away from the body, and toward the left side, and hold it by the thumb and index of the right hand in such manner that the small ring is away from the body.

Insert the index fingers, pointing downwards, into the small ring, and the thumbs, also pointing downwards, into the large loop. Draw tight.

With a turn of the wrists make the thumbs point upward. Pass the thumbs distal to the radial index string, and pick up the ulnar index string proximally.

Pass the little fingers distal to the radial index string, and pick up the ulnar thumb string proximally. Release thumbs.

Pass the thumbs proximally into the little finger loops, and pick up the radial little and ulnar index strings. Release indices.

Pindiki—The Rat Swimming.[1]

Release indices and Pindiki distal radial thumb strings—The Rat Under Water.

5. (Plate XXI.)—Two Swans=*Kungwari.* (South Australia).

Opening A.

Pass the thumbs distal to the index loops, and pick up the radial little finger strings proximally.

Bend the index fingers into their own loops, over the palmar strings. Release the little fingers, and turn up the indices away from you.

Pass the little fingers proximal to the index loops and into the thumb loops proximally, hook down the distal radial thumb string, then pass them towards you proximal to the radial thumb string, and pick up this string on their backs, returning proximal to the other strings. Release the thumbs.

Pass the thumbs proximal to the index loops, and into the little finger loops proximally. Pick up the radial little and ulnar index strings. Release the index fingers.

Pick up the ulnar thumb strings with the index finger proximally, and extend.

6. (Plate XXI.)—A Crane=*Krogwali.* (South Australia).

Collected by Miss C. Herdman.

Position 1, with a double twist in the centre, so that the radial string runs straight across, whilst the ulnar string loops round it.

Opening A.

Pass the thumbs distal to the radial index strings, and proximal to the ulnar index and radial little finger strings, and return, picking up these two strings on the back of the thumbs.

1 Roth (loc. cit.), pl. iv., No. 7.

Pass the little fingers distal to the radial index and ulnar thumb strings, and draw these strings out. Take the little fingers out of their loops, and reinsert them in the opposite direction.

There are now two triangles with their bases towards you; bend the index fingers into these distally, and on their backs pick up the inner string of each triangle. Release the thumbs.

Pass the thumbs through the little finger loops from the proximal side, and pick up the radial little and both ulnar index finger strings returning proximal to the radial index finger string.

Release the distal index loops.

With the index fingers pick up the distal ulnar thumb strings proximally.

Hook the right index over the distal left index loop, taking it off the finger, and hook the left index over the equivalent loop on the right index, and take it off the finger.

Release the thumbs and extend, turning the indices away from you.

7. (Plate XXI.)—A Jew Lizard. (Victoria)

Collected by Mr. J. W. Layard.

Opening A.

Release right index and pull tight.

*Pass the right thumb into the right little finger loop proximally, and pick up the radial string. Pass the right index over the palmar string, and into the thumb loop proximally, and pick up the ulnar thumb string.

With the left thumb and index take hold of the two radial thumb strings and lift them off the right thumb. Pass the right thumb away from you between its radial index and radial little finger strings, then turn it down and up towards you, thus picking up on its back the radial little finger string. Release the right little finger and transfer the right index loop to it.

Repeat from * twice.

Pass the right thumb into the right little finger loop proximally and pick up the radial string.

With the right thumb and index lift the left index loop off that digit, and place it over the whole left hand. Then take hold of the left ulnar thumb and radial little finger strings, release the left hand from all its strings, and replace the thumb and little finger loops.

Pindiki with the right index, and turn the hand away from you till the fingers point downwards, to extend the figure.

This figure represents a Jew Lizard (Amphibolurus barbatus), with its large head on the left, and its tail and back legs on the right, and is the same as Roth's "Fish" from Atherton (Pl. VII., Fig. 4).

8. (Plate XXII.)—A Corroboree=*Ewite.* (Cape York).

Opening A.

Place the big toe across the centre of all the strings. With the left thumb and index draw out the right ulnar thumb string proximal to the radial thumb string, pass the digits through this loop proximally, and draw out the radial index string; repeat with the ulnar index, and radial and ulnar little finger strings in turn. Release the little finger, and place the last loop on it.

Repeat with the other hand.

Release the toe, then place the ulnar little finger string in the centre of the figure, over the toe. Release the indices. Rotate the hands from side to side, and imitate the movements of the dance.

9. (Plate XXII.)—Making Fire=*Atundi.* (Cape York).

Hold part of the string with the thumbs and index fingers, the hands being about six inches apart. Make a small ring by passing the right hand clockwise (towards the body) towards the left side, and hold the loop by the thumb and index of the right hand in such manner that the small ring is away from the body.

Insert the index fingers, pointing downwards, into the small ring, and the thumbs, also pointing downwards, into the large loop. Draw tight and turn the thumb up.

Transfer the thumb loops to the index fingers.

Turn the left index downwards, and place each index loop on its hand in *Position 1.*

Another person puts his hand through the centre to represent the flame. Release right hand and pull off.

This figure resembles one from Torres Straits, called "Playing Ball," collected in 1898, by Dr. A. C. Haddon.[1]

10. (Plate XXII.)—A Cough=*Ole.* (Cape York).

Opening A.

Make The Crayfish (p. No. xxii.)

Pass the little fingers proximally into the triangles adjacent to the thumb loops, thus catching down the radial thumb string that runs straight across. Release thumbs.

1 Reports of the Cambridge Anthropological Expedition to Torres Straits, vol. iv., p. 336.

Pass the thumbs away from you (proximally) into the triangles adjacent to the index finger loops, picking up the radial index string that runs straight across. Release index fingers.

Pass the index fingers into the little finger loops and turn them up towards you, thus picking up the radial little finger string.

Extend and release thumbs, so that their loop unwinds with a jerk.

11. (Plate XXII.)—A Full Moon=*Akiana.* (Cape York).

Opening A.

Close together the fingers of each hand and pass them distally into the thumb loop, then turn them up, so that the radial thumb string passes to the ulnar side of the hand. Pass the thumbs proximal to the radial string (that comes from the back of the hand, and is the original ulnar thumb string), and allow the loop to slip on to the wrist.

Pass the thumbs towards you, then away, proximal to the wrist loop, but distal to the ulnar little finger string, catch this string on the backs of the thumbs and return. Release little fingers.

Pass the little fingers distal to the index loops and pick up the ulnar thumb strings proximally.

Exchange the index loops, passing the right through the left.

Pass the middle fingers distally through the index finger loops and pick up the ulnar thumb strings proximally.

Release the thumbs and indices, and then the little fingers, and extend.

12. (Plate XXII.)—Lightning=*Untemo.* (Cape York).

Opening A.

Pass the mouth proximal to the radial thumb string, distal to the radial cross, proximal to the ulnar cross, and catch hold of the ulnar little finger string, draw this out, pass it under the figure and place it over the toe.

Pass the thumbs into the index loops proximally and pick up the radial string. Navaho thumbs and release indices.

Pass the indices distal to the ulnar thumb strings, then bend them downwards, and into the little finger loops distally and turn them up towards you, picking up the radial little finger strings. Release thumbs.

Cf. Roth (loc. cit.), pl. xi., No. 5. "Two Rocks sticking out of the Water." Cape Grafton and Atherton.

Pick up the ulnar index string with the thumbs proximally. Release indices.

This represents a Thundercloud. Release the little fingers and pull tight sharply, and the lightning will flash out.

13. (Plate XXII.) = A Drum = *Aropa.* (Cape York).

Opening A.

Pass the middle fingers into the index loops distally, and pick up the radial index and ulnar thumb strings proximally. Release thumbs.

Pass the thumbs into the little finger loops proximally, and pick up the radial little and ulnar index finger strings proximally. Release little fingers.

Pass the little fingers distal to the middle finger loops and pick up the ulnar thumb strings proximally. Release thumbs.

Pass the thumbs into the little finger loops proximally, and pick up the radial little, and ulnar index finger strings proximally. Release the little fingers.

Pass the little fingers distal to the middle finger loops and pick up the ulnar thumb strings proximally.

Bend the index fingers over the palmar strings and into the middle finger loops distally, then turn them up towards you, picking up the (single) radial middle finger string. Release thumbs.

Pass the thumbs proximal to the ulnar little finger string and draw this string towards you, then pass them proximally into the middle finger loops; turn them down away from you, then up towards you, thus picking up the two ulnar middle finger strings.

Release all except the thumbs and extend gently.

Pass the little fingers proximally into the thumb loops and pick up on their backs one of the ulnar strings that runs straight across.

Pindiki and extend.

14. (Plate XXII.)—A Canoe = *Auto.* (Cape York).

Top Opening (See p. 125, No. 1).

Pass the right thumb distal to the proximal radial index string and pick up the proximal ulnar string on its back.

Pass the left thumb distal to the proximal index loop and pick up the distal ulnar string on its back.

Pass the little fingers distal to the distal index loop, and pick up the proximal radial index string on their backs.

Bend the index fingers, and, turning them up towards you, pick up on their tips the straight median string of the figure, beyond the twist.

Release the thumbs, then pass them into the little finger loops proximally, and pick up on their backs the oblique string (which runs straight across), and extend.

15. (Plate XXIII.)—A WATERSPOUT=*Mare*. (Cape York).

Make the Canoe.

Pass the thumbs distal to the oblique strings crossing the index loops, and pull this string down, then pass them to the palmar side of the palmar string, and pick this string up on their backs, returning through their original loops.

Release the little fingers, then pass them distal to the ulnar index string, and pick up proximally the radial index string (that runs straight across).

Pindiki the ulnar index string and extend, by separating the thumbs and indices, so that the radial thumb and the ulnar index strings are parallel and in a plane at right angles to the rest of the figure.

16. (Plate XXII.)—A LIZARD=*Yawundi*. (Cape York).

Opening A.

Pass the radial string over the rest and place it on the toe.

Exchange index loops, passing the right through the left one.

Pass the middle fingers distally through the index loops and pick up the ulnar thumb string on their backs, returning through the index loops.

Release the thumbs, indices and, little fingers and draw out, and the Lizard will run up a tree.

17. Plate (XXIII.)—TWO MEN=*Ama*. (Cape York).

Opening A.

Pass the thumbs distally through the index loops and pick up the radial little fingers strings proximally. Release indices, and navaho thumbs.

Take the thumb loops between the thumb and index fingers and pull the radial string so that the central loop decreases in size, then reverse, and it enlarges again.

Cf. Roth (loc. cit.), pl. xii., 2. "Canoe." Cape Grafton, Cape Bedford, Night Island, Princess Charlotte Bay.

This represents two men meeting and then going away again, and closely resembles one collected by Mrs. Jayne[1] from a Kopek Eskimo, and called "A Mouth."

18. (Plate XXIII.)—Two Men up a Tree=*Ama*. (Cape York).

Opening A.

Pass the radial thumb string distal to the other strings and place over the toe.

Bend the thumbs down proximal to all the strings and outside their respective toe strings; pick up these strings on their back, and return through the thumb loops.

Release the toe, and place each little finger loop on it. Release the index fingers and extend.

This represents two men up a tree.

19. (Plate XXIII.)—The Flying Foxes=*Unke*. (Cape York).

Opening A.

Take the left radial index string in the mouth and release both indices.

Pass the index fingers distally into the little finger loops, and pick up the radial string towards you, then pass them into the thumb loops distally and pick up the ulnar string away from you, letting the other string slip off.

Bend the thumbs away from you, catching down the oblique string of the index finger triangles and allowing their original strings to slip off. Release little fingers.

Release mouth, and the two flying foxes fly apart.

This figure is the same as the "Leashing of Lochiel's Dogs," from Scotland,[1] and appears to be almost universal, as it has been described from West and East Africa, from the Cherokee Indians and Eskimo, and figured by Roth (loc. cit.) as "Four-pronged Spear," Cape Bedford, *syn.* "Speared Kangaroo," Princess Charlotte Bay.

20. (Plate XXIII.)—Two Kangaroos=*Apo*. (Cape York).

Opening A.

Place the left index loop on the big toe (passing it distal to the little finger loop), and release both index fingers.

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1 "String Figures." Pub. Chas. Scribner & Sons, New York, 1906, p. 282.

1 Haddon. "Cats' Cradles from Many Lands," p. 73.

Pass the index fingers away from you, distal to the little finger loops, then bend them down towards you, proximal to these loops, and into the thumb loops distally. Turn them away from you again and return, picking up the ulnar thumb strings. Release thumbs.

Transfer the index loops to the thumbs.

Pick up the radial little finger strings with the thumbs proximally, and pindiki.

Release the toe, and draw the hands apart, and two Kangaroos will run away.

21. (Plate XXIII.)—A Mullet=*Yappa.* (Cape York).

Place the loop on the little fingers.

Pick up the left radial little finger string with the right thumb proximally, and the right radial little finger string with the left thumb proximally, distal to the right thumb loop.

Bend the index fingers away from you distal to the little finger loops, then proximal to them and into the thumb loops distally, straighten the index fingers away from you, picking up the ulnar thumb string, then bend them towards you into the thumb loop (distally), and pick up the radial thumb string. Release thumbs.

Pass the thumbs proximal to the distal radial and the ulnar index string and pick up the latter on their backs.

Release index fingers. Rotate the left hand till the fingers point downwards, to extend.

Release thumbs and pull tight quickly, and the fish is caught.

22. (Plate XXIV.)—A Cray-fish=*Alowga.* (Cape York).

Opening A.

Pass the thumbs proximal to the index loops, and into the little finger loops from the proximal side, turn them downwards over the ulnar little finger string picking this string up, and returning proximally to the other loops. Release the little fingers.

Pass the little fingers proximally into the index loop, and draw down the radial string.

Pass the index fingers distally into the thumb loops, and turn them away from you, thus picking up the two ulnar thumb strings through the original index loops. Release the little fingers.

To kill the Cray-fish.

Pass the little fingers proximally into the triangles adjacent to the thumb loops, thus catching down the radial thumb string.

Release the thumbs and pass them away from you into the triangle adjacent to the index finger loops, picking up on their backs the straight radial index string. Release the index fingers.

This figure is the same when finished as one collected by Mr. Stewart Culin[1] from Hawaii, as "A Pump."

23. (Plate XXIV.)—A DUGONG=*Matei.* (Cape York).

Opening A.

Release the right index and draw tight. Bend the left index into its own loop, catching down this string, and allowing its own to slip off.

Release the left thumb. Bring the left thumb and index together tip to tip, and slip the index loop on to the thumb.

Pass the left index to the radial side of the loose loop that runs to its palmar string, and pick up the radial string proximally, then pass it to the ulnar side of the ulnar string of this loop, and, turning up the index fingers towards you, pick up this string, letting the other slip off.

Similarly pick up with the right index the right ulnar thumb and the radial little finger strings.

Pass the little fingers into the index loops proximally, and hook down the oblique strings that run towards the centre of the figure, allowing the original little finger loops to slip off.

Release the thumbs, then pass them away from you into the space at the bottom of the figure, and pick up on their backs the strings that run straight across the figure. Release the little fingers.

This represents a Dugong, the left hand diamond is the head, and the right hand one is its tail.

24. (Plate XXIV.)—A SCRUB HEN=*Etanga.* (Cape York).

Position 1 on left hand.

Pass the right hand between the two pendant strings, and separate the thumb and the little finger widely, thus picking up on them the left thumb and little finger strings respectively, and draw out.

Release the left hand and repeat this movement with it.

Pass the thumbs proximal to the radial little finger string and pick it up.

Pass the little fingers proximal to the ulnar thumb string and pick it up.

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1 "Hawaiian Games." *American Anthropologist*, vol. i., No. 2 (n.s.), April, 1899, p. 222.

Do Opening A with single palmar strings.

Pass the radial thumb string distal to the rest, and place it over the toe. Slip thumbs out of this string.

Release little fingers, transfer the index loops to the thumbs, and place this double loop over the hands in Position 1.

Move hands towards and away from you to imitate the bird scraping together its mound.

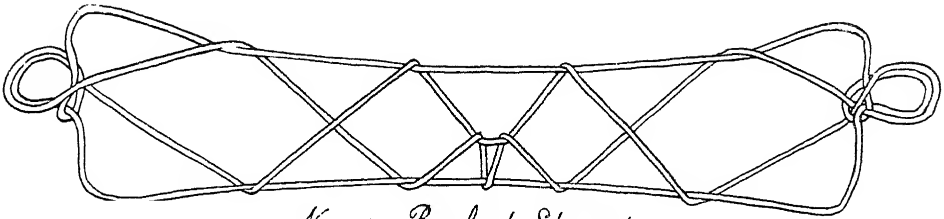
Take the loop off the hands and rotate through 180 degrees clockwise, and replace in Position 1, so that the ulnar little fingers strings are still ulnar, but lie over instead of under the toe strings.

Again imitate the bird scratching.

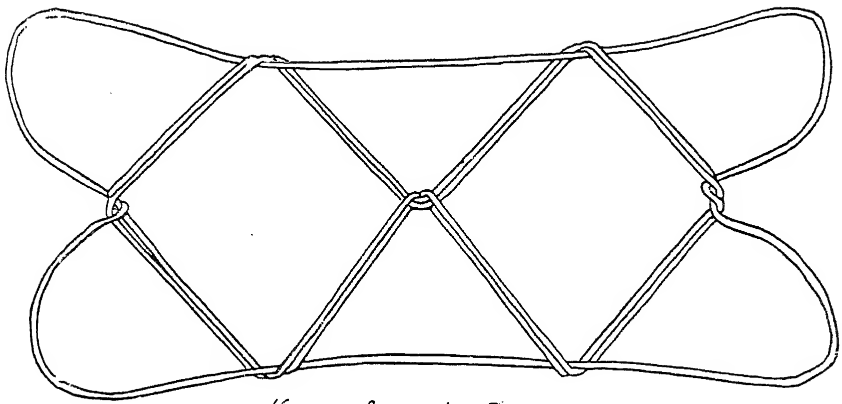
Release thumbs and lay figure down with the little finger strings nearest you.

Pick up on the indices their respective toe strings in the centre of the figure and draw out.

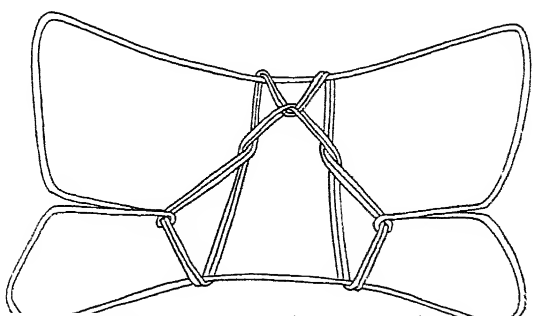
This represents the two eggs laid by the Scrub Hen.



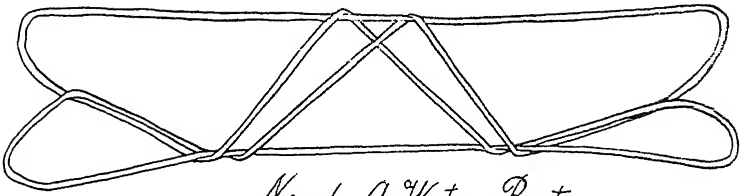
No. 1. Barbed Spears



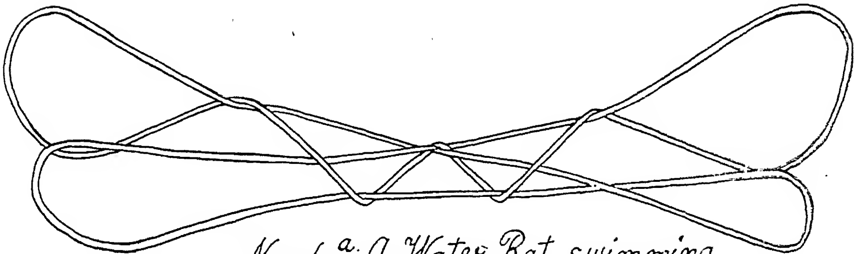
No. 2. Granite Rock



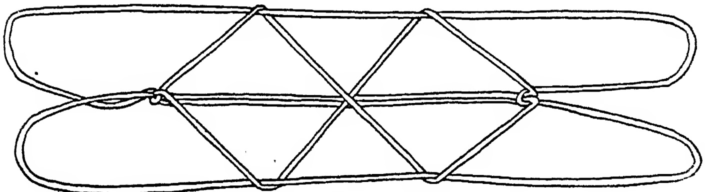
No. 3 A Night Owl



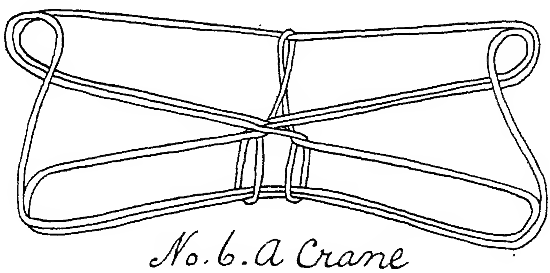
No. 4. A Water Rat



No. 4[a]. A Water Rat swimming

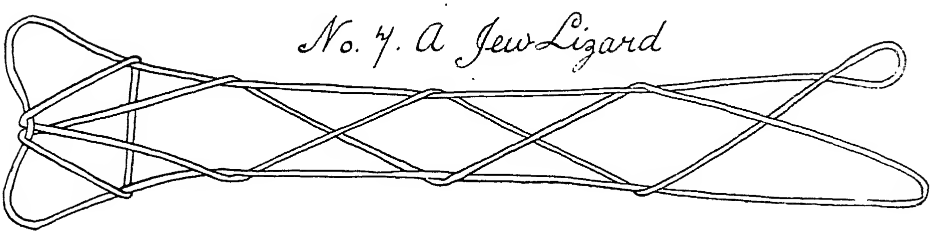


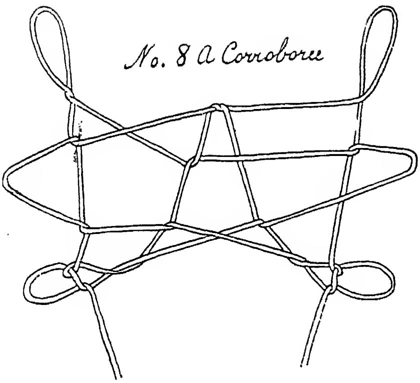
No. 5. Two Swans



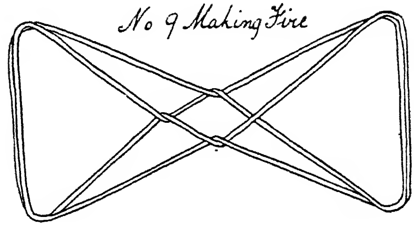
No. 6. A Crane

No. 7. A Jew Lizard

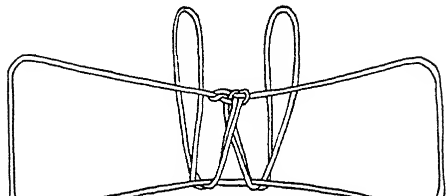




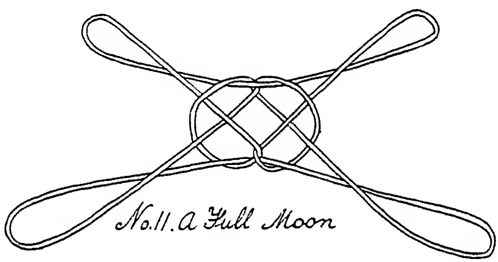
No. 8 A Corroboree



No 9 Making Fire

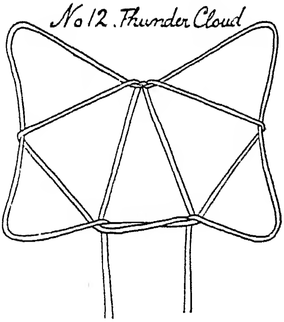


No. 10 A Cough

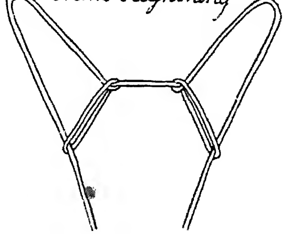


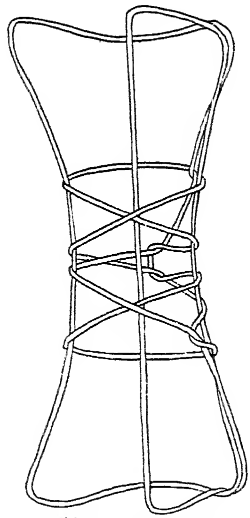
No. 11. A Full Moon

No 12. Thunder Cloud

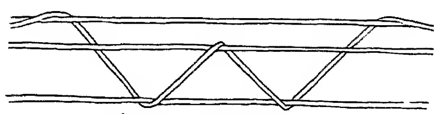


No. 12a. Lightning

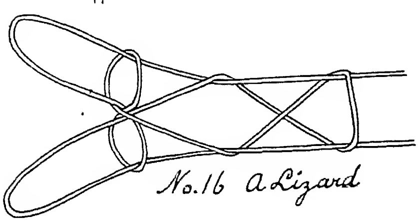




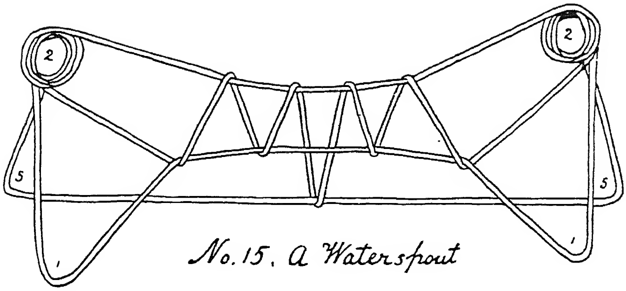
No. 13 A Drum



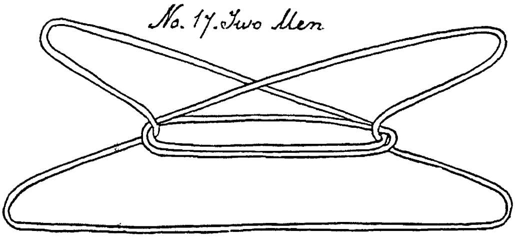
No. 14. A Canoe



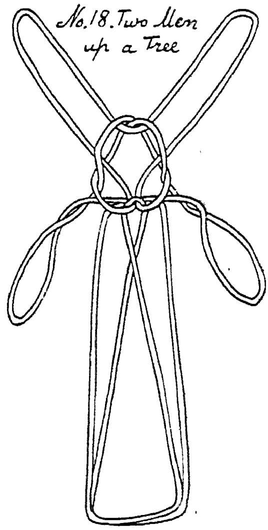
No. 16 A Lizard



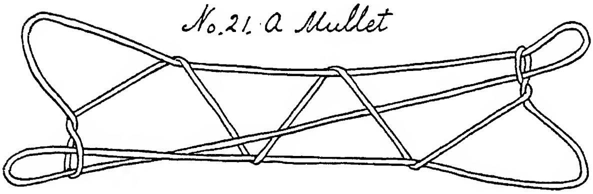
No. 15. A Waterspout



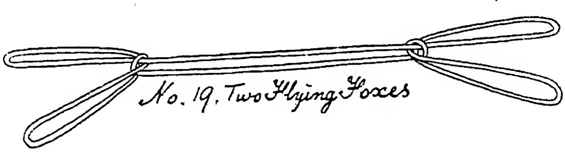
No. 17. Two Men



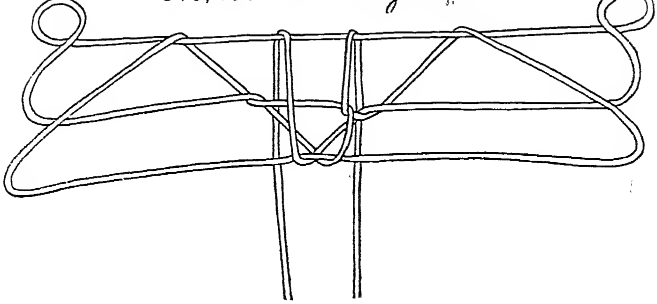
No. 18. Two Men up a Tree



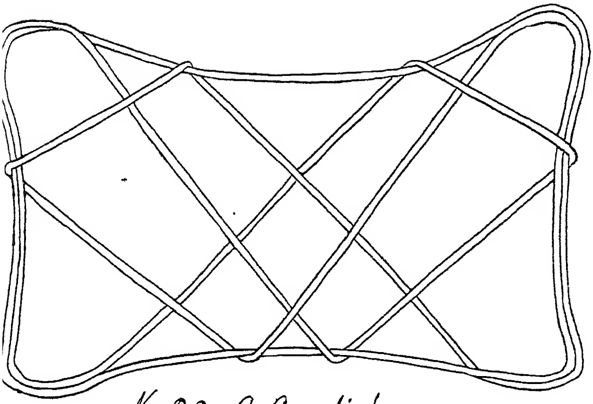
No. 21. A Mullet



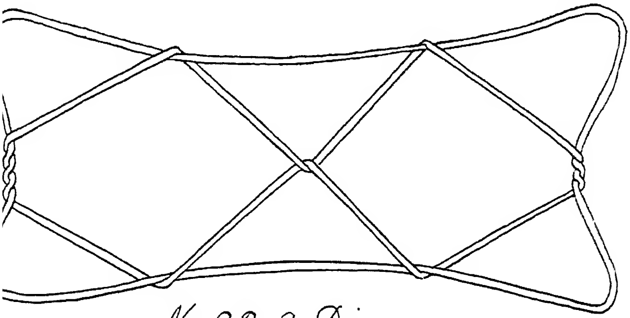
No. 19. Two Flying Foxes



No. 20. Two Kangaroos

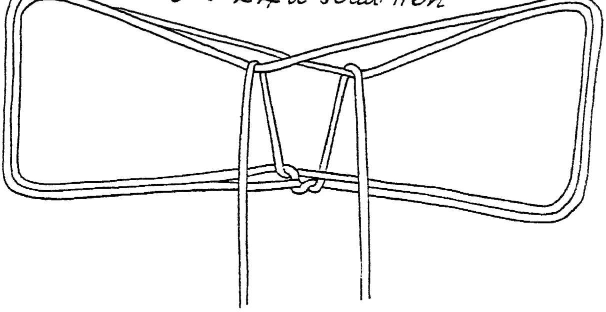


No. 22. A Crayfish

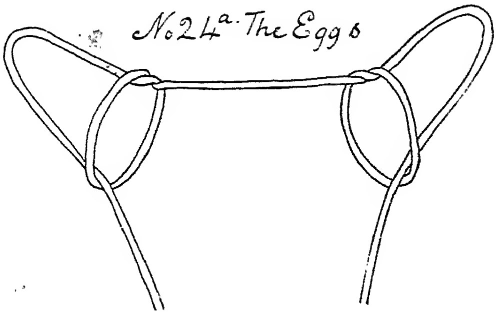


No. 23. A. Dugong

No. 24 A Scrub-Hen



No. 24a. The Eggs



[Proc Roy. Soc. Victoria, 30 (N.S.), Pt. II., 1918].

Art. X.—*A Method of Estimating Small Amounts of Calcium.*

By S. PERN, M.R.C.S., L.R.C.P. Eng.

(Communicated by Professor W. A. Osborne).

[Read 13th September, 1917].

For long there has been need of a simple and easy method of estimating small quantities of calcium, such as would be useful in clinical medicine. After some four years' experimenting the following method was found to be the most useful:—

To a slightly acid solution containing a soluble calcium salt, from three-quarters to an equal volume of methylated spirits is added without mixing, then a few drops of a saturated solution of oxalic acid, and the whole shaken up, almost immediately a white cloud appears.

The addition of small quantities of alcohol hastens the formation of calcium oxalate deposit, but on putting some of this white precipitate under the ultra-microscope no crystalline shape is observed, but small rounded masses about 0.1μ in diameter, and comparing them with a typhoid bacillus it was estimated it would take 128 to make up the same size.

In estimating the calcium content of the blood a small glass tube is marked to 1 c.c. content, and blood is drawn from a vein with a hypodermic syringe, and immediately transferred to the tube up to the 1 c.c. mark. This is placed at leisure in a platinum crucible, using a little distilled water to wash out the tube; the wash water is also transferred to the crucible. It is then passed to and fro through a strong flame,and with practice one is able to burn the blood to a black ash without any bubbling over or spluttering, which is inevitable if it is dried off first. It has also the advantage of being rapid. It is then placed in a small electric furnace, which is already at a dull red heat, and left there till thoroughly ashed, about half an hour being ample. During the ashing, controls and filter papers are prepared.

For the nephelometric method the writer uses glass tubes of an even bore with flat bottoms about 8 cm. long and marked in 1 c.c. gradations. Total capacity would be about 8 c.c. Double filter papers are used 4 cm. in diameter and very small glass funnels. The filter-papers are rinsed through with 4 c.c. of 2 per cent. acetic acid, which is found sufficient to eliminate all traces of soluble Ca from them. This is necessary, as Mr. H. Lyman

pointed out that all filter-papers, even the best Swedish, contain noticeable amounts of calcium. When the crucible is cool, 1 c.c. of 2 per cent. acetic acid is added by means of a graduated pipette with rubber teat. It is stirred round with a glass rod, rinsing the rod after each use. The contents are drawn up with a pipette and filtered, the same care being taken by rinsing the pipette each time. Another 1 c.c. of 2 per cent. acetic acid is again added to the crucible, and after agitating is filtered. 0.5 c.c. of distilled water is used to wash out the crucible, and then passed through the filter-papers, making a total of 2.5 c.c. in the tube. A solution of a calcium salt, phosphate or chloride in dilute acetic acid is used of the strength of 0.0025 grms. of calcium per 1 c.c., for controls 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2 c.c. are used, giving a wide range which represents 0.015, 0.0175, 0.02, 0.0225, 0.025, 0.0275, 0.03 mg. of calcium. These are placed in the tubes and filled up to 2.5 c.c. with distilled water

Now all is ready for testing

Add 1.5 c.c. of alcohol (ordinary methylated spirits, if calcium-free, will do), then three drops of a saturated solution of oxalic acid with a dropper. They are all shaken as rapidly as possible, and within a few minutes the results can be read by looking down the tubes and comparing with the controls.

A 10 per cent. variation even in such small quantities can be estimated by this somewhat crude nephelometric method, and with the advent of one of the new instruments finer grades will easily be obtained.

Since completing this method Mr. H. Lyman has shown that a large percentage of the calcium can be picked up by mixing the blood with twice or three times its volume of a 6.5 per cent. solution of trichloracetic acid, and as a clinical test the following gives a fair degree of accuracy and is rapidly carried out.

Dilute a given quantity of blood with twice its volume of a 6.5 per cent. solution of trichloracetic acid and allow to stand for twenty-four hours, by then there will be a clear fluid above the precipitated proteins, 2 c.c. of this is pipetted off and neutralised till faintly acid, it is transferred to the nephelometric tube and equal quantities of methylated spirit added, then three drops of a saturated solution of oxalic acid, and shaken. The result can be read against controls within a few minutes, giving one-third of 2 c.c. of blood.

My thanks are tendered to your President, Professor Osborne, for much advice and help during these investigations.

[Proc. Roy. Soc. Victoria, 30 (N.S.), Pt. II., 1918].

Art. XI.—*Chiloglottis Pescottiana, sp. nov.*

By R. S. ROGERS, M.A., M.D.

(Communicated by Professor A. J. Ewart, D.Sc.).

(With Plate XXV.).

[Read 8th November, 1917].

A slender glabrous plant 3 to 7 inches high; with two basal leaves on long petioles, oblong-lanceolate, of varying length and width, usually $1\frac{1}{2}$-2 inches long; one bract, sheathing, acuminate, situated above the middle of the stem. Flowers single, greenish-bronze, with dark purple calli.

Lateral sepals linear-lanceolate, recurved, connate at the extreme base; dorsal sepal spathulate-acuminate, more or less incurved over column and about same length as lateral sepals. Lateral petals spreading, lanceolate, much wider, but about same length as lateral sepals. Labellum oblong, quite rounded at tip, on a very short moveable articulation, rather shorter than lateral sepals, slightly recurved about the middle of lamina. Calli dark-purple distributed as follows:—(1) One large crescentic sessile callus in middle line in advance of all the others; (2) a large bilobed stalked callus about midway between this and base of lamina; (3) numerous stalked calli, small and medium sized, between (1) and (2); (4) a somewhat irregular row of small stalked calli running on either side of the middle line from the bend in the lamina to its base. Column shorter than dorsal sepal, winged especially in its upper part, the wings being produced into two short falcate processes above and behind the anther; anther blunt, situated on apex of column immediately above the circular stigma, as in a Caladenia.

The genus Chiloglottis includes six recorded Australian species, four of which have been described by the late R. D. Fitzgerald. One of the latter occurs also in New Zealand and another indigenous species is also recorded from those islands.

The new species is very distinctive and the shape of the labellum alone readily distinguishes it from all others.

The following analytical table will differentiate it from other Australian members of the genus.

I. Petals reflexed.

Labellum more or less obovate, on a claw shorter than the lamina. A few stalked calli on the proximal end of the claw; a large prominent, reflexed, usually green callus at base of lamina; numerous crowded brown calli of varying shapes and sizes in front of this basal callus extending nearly to the tip ... ... 1. *C. diphylla.*

Labellum ovate, on a claw about as long as lamina. One group calli at base of lamina, the most prominent of these being a large stalked bilobed gland, the others thick more or less sessile glands, surrounded by small calli with slender stalks; a second large group of small sessile calli in front of the first extending to tip of labellum 2. *C. formicifera.*

Labellum rhomboidal on a claw shorter than lamina. No calli on claw; lamina with a single, large, stalked, compound, brown callus near base .. 3. *C. trapeziforme.*

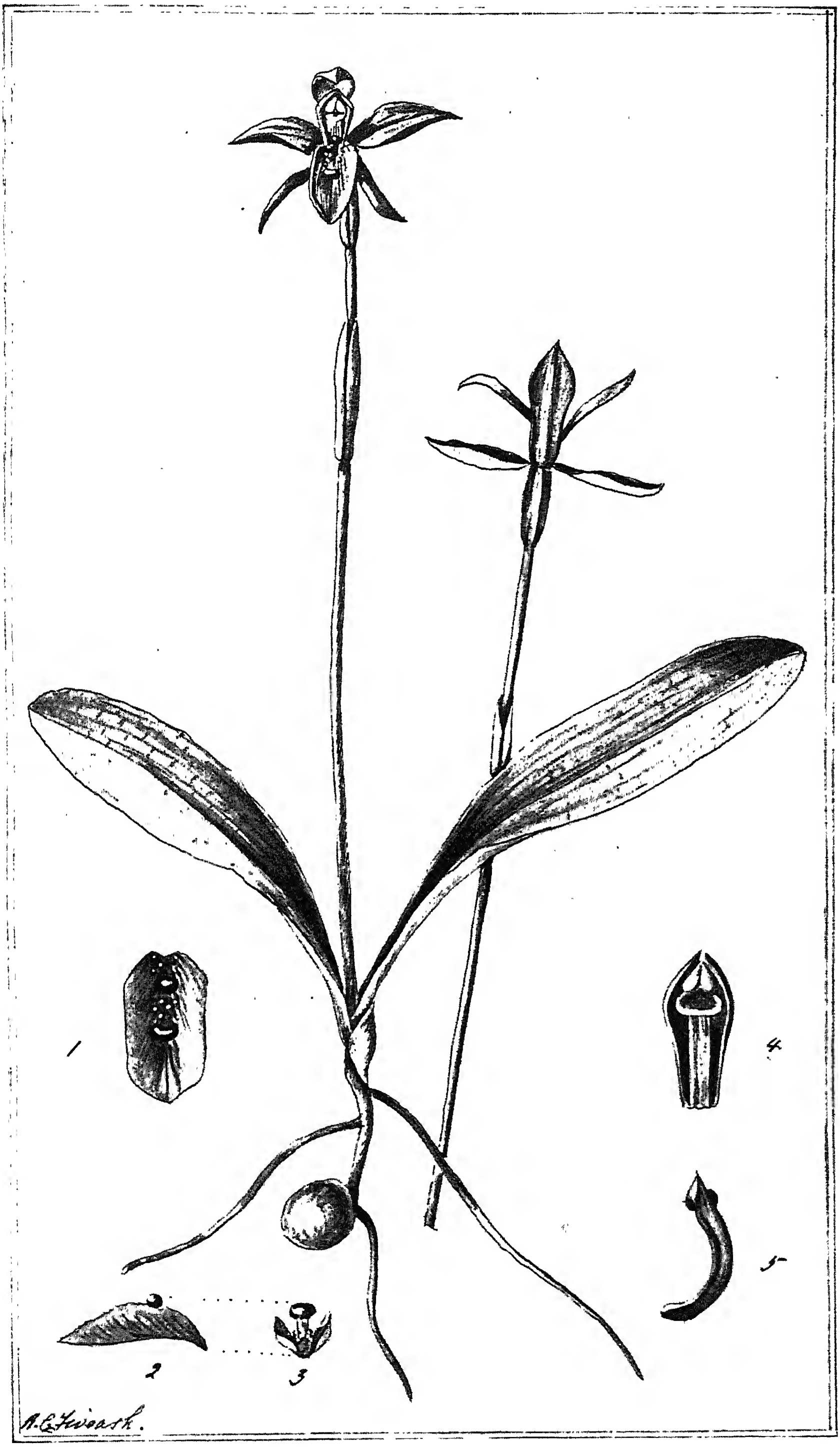
II. Petals spreading or ascending.

Flowers reddish-brown. Petals ascending. Labellum broadly ovate on a very short claw. A large, brown, long stalked, clavate callus at base of lamina and a short thick, almost sessile, gland in front of this near the centre; a somewhat irregular row of small stalked calli on either side of these ... ... 4. *C. Gunnii.*

Flowers green. Petals spreading. Labellum ovate or very broadly lanceolate, on a very short claw. Lamina with shortly stalked or sessile brown calli irregularly grouped in centre and at base 5. *C. Muelleri.*

Flowers reddish-brown. Petals spreading. Labellum obovate on broad claw. One large reflexed greenish callus at base of lamina, and other large, flat sessile calli along centre surrounded by many small, clavate, stalked calli ... 6. *C. trilabra.*

Flowers greenish-bronze. Petals spreading. Labellum on very short claw. One large, purple, crescentic, sessile callus in middle line in advance of all the others; another large, bilobed stalked callus about midway between this and base of lamina; numerous stalked calli, small and medium-sized, situated between these two groups; a somewhat irregular row of small stalked calli running on either side of middle line from bend of lamina to its base ... ... 7. *C. Pescottiana.*



Chiloglottis Pescottiana, sp. nov.

The species is named in honour of Mr. E. E. Pescott, F.L.S., of Melbourne, who supplied me with specimens from Tallangatta, Victoria—the same locality from which C. trapeziforme, Fitz., has recently been recorded as new to the State. It was discovered by Mr. A. B. Braine, and it blooms from the latter end of September to the beginning of December.

It would appear to be fairly numerous, but very local in its distribution.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. XII.—*Magnetic Deflection of β-Rays: Tabulation of* v *against* RH *assuming Lorentz Theory.*

BY MISS N. C. B. ALLEN, B.Sc.

(Communicated by Professor T. H. Laby, M.A.).

[Read 8th November, 1917].

The negative electron, when it possesses a velocity v cms/sec, is deflected by a uniform magnetic field, H gauss, at right angles to its direction of motion, into a circular path of radius R cms. such that $RH = vm/e$, m grams being the transverse mass of the negative electron for a velocity v cms/sec. $m = m_o \phi(\beta)$, where $\beta = v/V$, V cms/sec being the velocity of light. In experiments on cathode and β rays it is frequently necessary to calculate the velocity of the rays when RH is known. Since e/m_o is now well known, and Lorentz's theory that $m = m_o(1-\beta^2)^{-\frac{1}{2}}$ has been confirmed by Bucherer, it is convenient to tabulate v with RH as argument.

The following values for e/m_o have been obtained by different observers:—

Bucher	1908 ...	1.763×10^7 E.M.U.gm^{-1}
Classen	1908 ...	1.776
Wolz	1909 ...	1.767
Lerp	1911 ...	1.72
Malassez	1911 ...	1.769
Bestelmeyer	1911 ...	1.75
Bestelmeyer	1911 ...	1.766
Alberti	1912 ...	1.756
Jones	1914 ...	1.75

From a consideration of these the value 1.763×10^7 was chosen for e/m_o. The velocity of light was taken as 2.9986×10^{10} cms/sec.

The table expresses RH in gauss-cms and v in 10^8 cms/sec. **Example**: If $RH = 2315$ gauss-cms. then $v = 241.64 \times 10^8$ cms./sec.

RH	v 0	10	20	30	40	50	60	70	80	90	Mean Differences. 1	2	3	4	5	6	7	8	9
0 -	.0	1.763	3.526	5.288	7.050	8.811	10.571	12.331	14.088	15.845	176	352	528	704	880	1056	1232	1408	1584
100 -	17.600	19.353	21.104	22.852	24.599	26.343	28.084	29.822	31.588	32.290	174	348	523	697	871	1045	1219	1394	1568
200 -	35.02	36.74	38.46	40.18	41.89	43.60	45.31	47.01	48.71	50.40	17	34	51	68	85	102	119	137	154
300 -	52.09	53.77	55.44	57.11	58.78	60.44	62.09	63.74	65.38	67.02	17	33	50	66	83	99	116	132	149
400 -	68.65	70.27	71.89	73.50	75.10	76.70	78.29	79.87	81.44	83.01	16	32	48	64	80	96	111	127	143
500 -	84.57	86.12	87.67	89.21	90.74	92.26	93.78	95.29	96.78	98.27	15	30	46	61	76	91	106	122	137
600 -	99.76	101.23	102.69	104.15	105.60	107.04	108.47	109.90	111.31	112.72	14	29	43	57	72	86	101	115	129
700 -	114.12	115.51	116.89	118.27	119.63	120.98	122.33	123.67	125.00	126.32	14	27	41	54	68	81	95	108	122
800 -	127.63	128.93	130.23	131.51	132.78	134.05	135.31	136.55	137.79	139.02	13	25	38	50	63	76	88	101	113
900 -	140.24	141.46	142.66	143.85	145.04	146.22	147.39	148.56	149.71	150.85	12	23	35	47	59	70	82	94	106
1000 -	151.98	153.10	154.22	155.32	156.42	157.51	158.60	159.67	160.74	161.79	11	22	33	43	54	65	76	87	98
1100 -	162.84	163.88	164.91	165.94	166.95	167.96	168.96	169.94	170.93	171.90	10	20	30	40	50	60	70	80	90
1200 -	172.87	173.82	174.77	175.71	176.65	177.58	178.50	179.41	180.31	181.21	9	18	28	37	46	55	65	74	83
1300 -	182.10	182.98	183.85	184.71	185.57	186.42	187.26	188.10	188.93	189.75	8	17	25	34	42	51	59	68	76
1400 -	190.57	191.38	192.18	192.97	193.76	194.54	195.31	196.08	196.84	197.59	8	16	23	31	39	47	54	62	70
1500 -	198.34	199.08	199.81	200.54	201.26	201.98	202.69	203.40	204.09	204.77	7	14	21	28	36	43	50	57	64
1600 -	205.46	206.14	206.81	207.48	208.14	208.79	209.44	210.08	210.72	211.35	7	13	20	26	33	39	46	52	59
1700 -	211.98	212.60	213.21	213.83	214.43	215.03	215.63	216.22	216.81	217.38	6	12	18	24	30	36	42	48	54
1800 -	217.95	218.52	219.08	219.64	220.20	220.75	221.29	221.83	222.36	222.89	5	11	16	22	27	33	38	44	49
1900 -	223.42	223.94	224.46	224.97	225.48	225.98	226.48	226.97	227.46	227.95	5	10	15	20	25	30	35	40	45
2000 -	228.43	228.91	229.38	229.85	230.31	230.77	231.23	231.68	232.13	232.58	5	9	14	18	23	27	32	37	41
2100 -	233.01	233.45	233.89	234.32	234.75	235.17	235.59	236.01	236.42	236.83	4	8	13	17	21	25	30	34	38
2200 -	237.23	237.63	238.03	238.42	238.82	239.20	239.59	239.97	240.35	240.72	4	8	12	15	19	23	27	31	35
2300 -	241.09	241.46	241.83	242.20	242.56	242.91	243.26	243.62	243.96	244.31	4	7	11	14	18	21	25	28	32
2400 -	244.65	244.99	245.32	245.66	245.99	246.32	246.65	246.97	247.29	247.61	3	7	10	13	16	20	23	26	30
2500 -	247.93	248.24	248.55	248.85	249.16	249.46	249.76	250.06	250.36	250.65	3	6	9	12	15	18	21	24	27
2600 -	250.94	251.22	251.50	251.79	252.07	252.35	252.63	252.91	253.18	253.45	3	6	8	11	14	17	19	22	25
2700 -	253.72	253.99	254.25	254.51	254.77	255.02	255.28	255.53	255.78	256.03	3	5	8	10	13	15	18	20	23
2800 -	256.28	256.53	256.76	257.01	257.25	257.49	257.73	257.97	258.20	258.43	2	5	7	10	12	14	17	19	21
2900 -	258.66	258.88	259.11	259.33	259.56	259.78	260.00	260.21	260.43	260.64	2	4	7	9	11	13	15	18	20
3000 -	260.85																		

RH	v 0	100	200	300	400	500	600	700	800	900	Mean Differences. 10	20	30	40	50	60	70	80	90
3000 -	260.85	262.89	264.78	266.54	268.18	269.70	271.12	272.45	273.69	274.86	15	30	45	60	76	91	106	121	136
4000 -	275.95	276.97	277.93	278.83	279.69	280.49	281.25	281.96	282.64	283.28	8	16	24	32	40	48	56	63	71
5000 -	283.88	284.46	285.00	285.52	286.00	286.47	286.92	287.34	287.74	288.13	5	9	14	18	23	28	32	37	41
6000 -	288.49	288.84	289.18	289.50	289.80	290.09	290.37	290.64	290.90	291.15	3	6	9	12	14	17	20	23	26
7000 -	291.38	291.61	291.83	292.04	292.24	292.43	292.62	292.80	292.98	293.14	2	4	6	8	10	12	13	15	17
8000 -	293.30	293.46	293.61	293.76	293.90	294.03	294.16	294.28	294.40	294.52	1	3	4	5	7	8	9	11	12
9000 -	294.64	294.76	294.87	294.97	295.07	295.17	295.26	295.35	295.44	295.53	1	2	3	4	5	6	7	8	9
10,000 -	295.62																		

RH	v 0	1000	2000	3000	4000	5000	6000	7000	8000	9000	Mean Differences. 100	200	300	400	500	600	700	800	900
10,000 -	295.62	296.34	296.89	297.33	297.67	297.95	298.19	298.38	298.53	298.66	3	6	10	13	16	19	22	25	29
20,000 -	298.79	298.89	298.97	299.04	299.11	299.17	299.22	299.27	299.31	299.34	1	1	2	2	3	4	4	5	5
30,000 -	299.38	299.41	299.45	299.47	299.49	299.51	299.53	299.54	299.56	299.58	0	0	1	1	1	1	1	2	2
40,000 -	299.59	299.60	299.61	299.62	299.63	299,64	299.66	299.67	299.68	299.68	0	0	0	0	1	1	1	1	1
50,000 -	299.69																		

RH	v 0	10,000	20,000	30,000	40,000	50,000	60,000	70,000	80,000	90,000	Mean Differences. 1000	2000	3000	4000	5000	6000	7000	8000	9000
50,000 -	299.60	299.74	299.77	299.79	299.81	299.82	299.82	299.83	299.83	299.84	0	0	0	1	1	1	1	1	1
150,000 -	299.84	299.84	299.84	299.85	299.85	299.85	299.85	299.85	299.85	299.85	0	0	0	0	0	0	0	0	0
250,000 -	299.85																		

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. XIII.—*On the Occurrence of Acrotreta in Lower Palaeozoic (Lancefieldian and Heathcotian) Shales in Victoria.*

BY FREDERICK CHAPMAN, A.L.S., &c.

(Palaeontologist, National Museum, Melbourne).

(With Plate XXVI.).

[Read 8th November, 1917].

General Remarks.

The specimens forming the basis of the present paper come from two sources.

(1) The better preserved specimens, dorsal and ventral valves, were found by Professor Skeats, D.Sc., in a road-metal heap E. of Mount William railway station and N.E. of Lancefield. The matrix is a whitish or pale ashen grey siliceous shale, with obscure crustacean remains (cf. *Hymenocaris*). In thin sections under a high power, small cruciform spicules can be distinguished, probably referable to *Protospongia*.

(2) A smaller and slightly crushed and distorted interior of a dorsal valve, apparently belonging to the same species, was found by the late Dr. T. S. Hall, M.A., near Lancefield, which he presented to the Museum in 1908.

When first examining Prof. Skeats' specimens, I was struck with their resemblance to certain Cambrian brachiopods formerly placed in the genus *Linnarssonia* by C. D. Walcott, which genus has since been merged into *Acrotreta*, Kutorga. *Acrotreta* is a genus of more or less cone-shaped brachiopods in which the pedicle opening is simple, circular and apical on the central valve. The false cardinal area is apparent in the cast of the ventral valve in one of the present specimens.

Acrotreta antipodum, sp. nov. (Plate XXVI.)

Description.—Valves wider than long, subovate in outline; posterior obtuse to depressed, with a false cardinal area. Ventral valve moderately high; pedicle opening situated about one-fifth from the posterior margin, apex concavely sloping to the posterior,

and gently convexly to the anterior margin. The exterior of a ventral valve shows the ornament to be strongly concentric (tegulate), the edges of the concentric laminae being acerate or sparsely spinose. An exfoliated dorsal valve shows the impression of the median septum with divergent furrows and rhomboidal termination; also muscle scars near the hinge. The interior of the dorsal valve from Lancefield (somewhat distorted) shows the median septum and lateral scars.

Dimensions.—Ventral valve—length (in all the figured specimens from the Mount William district), 2.25 mm.; width, 2.75 mm. Dorsal valve—length, 1.25 mm.; width, 1.5 mm.

The smaller specimen, from the black shale of Lancefield, has a length of 1.5 mm., and a similar width, the latter probably due to a lateral distortion.

Occurrence.—Ventral and dorsal valves in grey siliceous shale from stone heap E. of Mount William railway station. Collected by Prof. E. W. Skeats, D.Sc. Dorsal valve in black Lower Ordovician shale, Lancefield. (Coll. by Dr. T. S. Hall, M.A.; pres. 4.3.08).

Relationships.—The above species belongs to the group of depressed *Acrotretæ*, of which *Acrotreta sagittalis*, Davidson sp.[1] forms a central type. In that species the valves are not so laterally widened as in the Victorian, and in this respect there is a nearer approach to the present species in *Acrotreta belti*, Davidson sp.[2], in which again the laterally ovoid outline is not so pronounced as in *A. antipodum*. In the surface ornament *A. sagittalis*, by its concentric laminae, shows closer affinity with *A. antipodum*, but it is not so strong, nor even inclined to spinosity as in the Victorian species. *A. sagittalis* is a Menevian fossil in Wales, and *A. belti* occurs in the Lower Tremadoc.

Another related form is *Acrotreta bellatula*, Walcott,[3] a Middle Cambrian species from Millard County, Utah. This is a depressed form, having a more circular outline, and with the apex close to the posterior margin; whilst the surface of the valve is moderately smooth or finely concentric.

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1 *Obolella sagittalis*, Salter MS. Rep. Brit. Assoc., 1865, p. 285.
Discina labiosa. Idem, ibid (name only).
Obolella sagittalis, Davidson. Geol. Mag., vol. v., 1868, p. 309, pl. xv., figs. 17-24.
Linnarssonia sagittalis, Dav. sp. Hall and Clarke, Pal. N. York, vol. viii., pt. i., 1892, p. 108.

2 *Obolella belti*, Davidson. Geol. Mag., vol. v., 1868, p. 310, pl. xv., figs. 25-27.

3 Smithsonian Misc. Coll., vol. liii., 1908, p. 93, pl. ix. figs. 4, 4a, b.

In the St. John Group (Middle Cambrian), of New Brunswick, *Acrotreta transversalis*, Hartt sp. occurs[1] which form, belonging to the *A. sagittalis* group, is strikingly like the Victorian species, except in surface ornament.

Summary.

The group to which the present species is closely allied is Middle Cambrian in America (St. John Group), and Middle and Upper Cambrian (Menevian and Tremadoc) in Wales. Further light is thus thrown upon the homotaxial relationship of the Victorian lowest palaeozoic strata with that of other widely separated areas, by the discovery of the above fossils, and in view of the results of the recent examination by the writer, of the Heathcotian fauna, there is perhaps little, if any doubt, that these Heathcotian beds should now be regarded as of Upper Cambrian age. Since the Heathcotian has already been shown by Professor Skeats[2] to form one continuous series with the Lower Ordovician (Lancefieldian), it is now more difficult than ever to draw a distinct line between the Upper Cambrian and the Lower Ordovician in Victoria, and the occurrence of the form of *Acrotreta* herein described from Lancefield goes further to show that, in the Lancefieldian itself, as is well known, a fair number of Cambrian fossil types coexisted with Ordovician forms. Thus, *Clinograptus tenellus* is Cambrian in some beds elsewhere, *Bryograptus* is Cambrian in Europe and both Upper Cambrian and Lower Ordovician in New York State, whilst the oldest species of *Tetragraptus* seem to represent the transitional zones between Cambrian and Ordovician.

In conclusion, I wish to express my thanks to Mr. R. A. Keble for confirmatory evidence regarding the distribution of the graptolites.

EXPLANATION TO PLATE XXVI.

Fig. 1.—*Acrotreta antipodum*, sp. nov. Exterior of ventral valve. Probably Heathcotian. Mount William district. × 10.

,, 2.—Ditto. Surface ornament, enlarged. × 30.

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1 *Obolella transversa*, Hartt. Bull. U.S. Geol. Surv., No. 10, 1868, p. 644, pl. i., fig. 55a. *Linnarssonia transversa*, Hartt sp. G. F. Matthew, Trans. R. Soc. Can., vol. iii., sect. iv., 1885, p. 35, pl. v., figs. 11, 11*a-e*.

2 "On the Evidence of the Origin, Age and Alteration of the Rocks near Heathcote, Victoria." Proc. Roy. Soc. Victoria, vol. xxi. (n.s.), pt. i., 1908, p. 302.

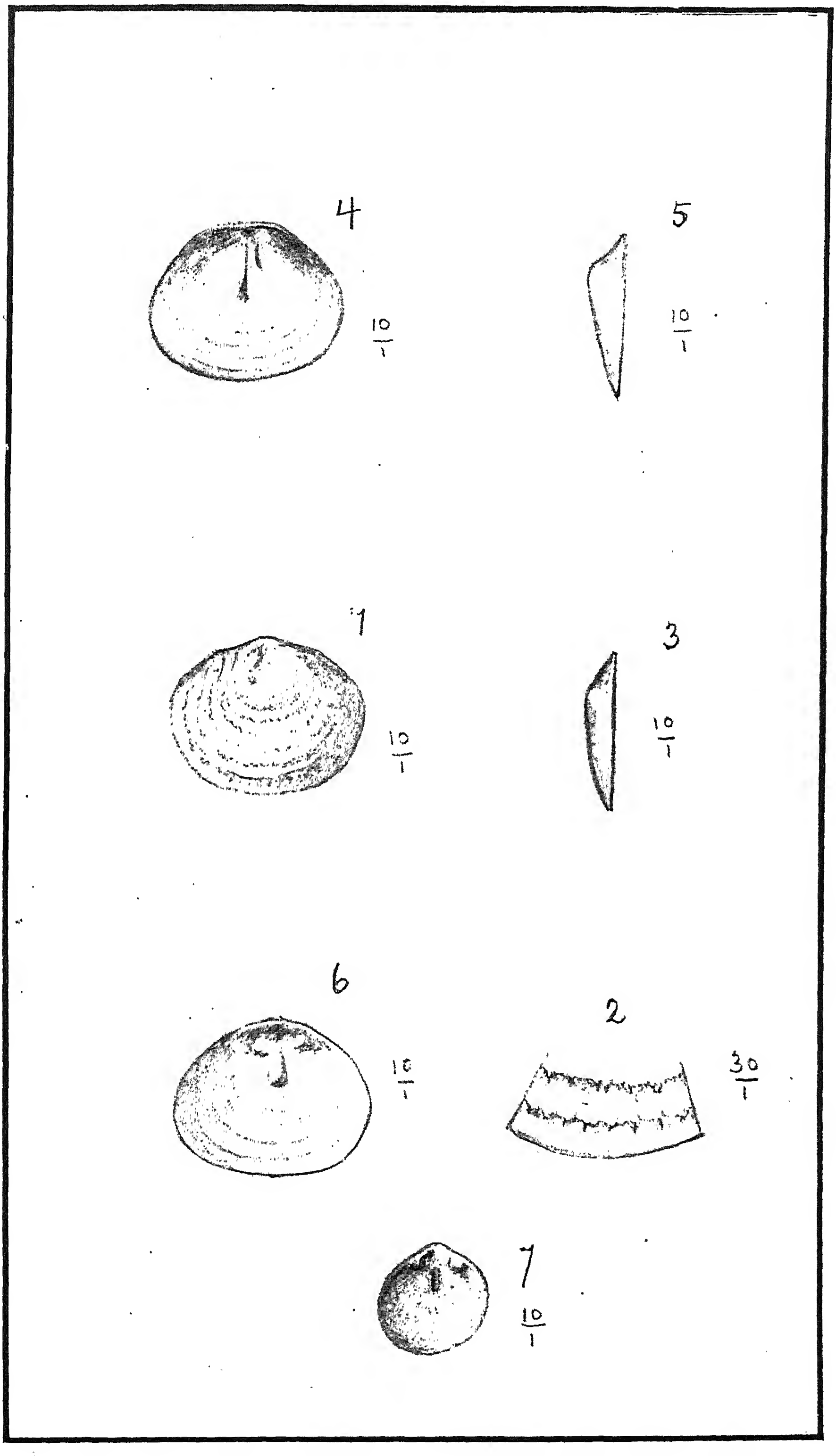
,, 3.—Ditto. Profile of valve. × 10.

,, 4.—An exfoliated dorsal valve, showing impression of median septum. Probably Heathcotian. Mount William district. × 10.

,, 5.—Ditto. Profile of valve. × 10.

,, 6.—Ditto. Interior of dorsal valve. Probably Heathcotian. Mount William district. × 10.

,, 7.—Interior of dorsal valve, showing median septum and muscle scars. Lower Ordovician. Lancefield. × 10.



F.C. ad. nat del. Acrotreta antipodum, Ch., Lower Palaeozoic, Victoria

[Proc. Roy. Soc. Victoria, 30 (N.S.), Pt. II., 1918].

Art. XIV.—*On an Apparently New Type of Cetacean Tooth from the Tertiary of Tasmania.*

By FREDERICK CHAPMAN, A.L.S., &c.

(Palaeontologist, National Museum, Melbourne).

(With Plate XXVII.)

[Read 8th November, 1917].

Introduction.

The fossil tooth which forms the subject of the following note was kindly lent to the National Museum by Mr. H. H. Scott, the Curator of the Victoria Museum, Launceston, with permission for its description. It was bequeathed to the Victoria Museum by Miss Lodder, who found it in 1897 washed up with "two other (?) similar fossils," at the mouth of the Leven, at Ulverstone, about 28 miles east of Table Cape.

It seems probable from the comparable evidence obtainable regarding the relationship of this tooth that it is allied to that of the Sperm Whale, but with the difference that, instead of being a curved, cylindrical cone, the tooth is much flattened in contour, has an extremely wide base and a bevelled apex or crown. The absence of any true enamel at the apex further points to its relationship with the *Physeteridae*. It is without doubt a tooth of the mandibular series, those of the upper jaw in this family being stunted, and are buried in the dense ligamentous gum.[1] In view of its apparent distinctness from the living *Physeter macrocephalus* a new generic name is here suggested.

Genus Scaptodon,[2] nov.

Generic Characters.—Tooth conical, depressed, curved, gradually tapering from base to apex, depressed elliptical in section. Root much larger than crown. Base of crown not contracted.

1. See Tomes: Manual of Dental Anatomy (7th ed., Tims and Hopewell-Smith), 1914, p. 493. Also Ritchie and Edwards: "On the occurrence of functional teeth in the upper jaw of the sperm whale." Proc. R. Soc. Edin., vol. xxxiii., pt. ii., No. 15, 1913, pp. 166-168, pl. xxxiii. Those authors show that the maxillary teeth of *Physeter macrocephalus* are flattened at the apex and oval in section; they bear no resemblance to the present form of tooth.

2. From σκαπτω, to dig, and ὀδους, a tooth, in allusion to the trowel-ended apex.

Pulp cavity moderately deep. Root entirely covered with cement. Crown bevelled on inner, concave side and surface radiately grooved.

Scaptodon lodderi, gen. et. sp. nov. (Plate XXVII., Figs. 1-3).

Description.—Tooth (mandibular), large, conical, tapering from a wide base to a narrow crown; much depressed and widely curved, in basal section, long elliptical. The base is open, and has a moderately deep pulp cavity. The whole of the root, so far as preserved, was covered with a fairly thick layer of cement; the surface is relieved by a series of shallow longitudinal furrows extending from the base through more than half the length. The crown can scarcely be separated, being continuous in contour, with the root, and is apparently marked off at the limit of the bevel. The apex of the crown is bevelled to a sharp cutting edge towards the convex side, the bevelled surface being marked with some low radiating ridges producing a few serrations on the cutting edge, the latter having a parabolic curvature.

Measurement.—Length of tooth, measured along the convex face, 113 mm. Greatest width of tooth at base of root, 41 mm.; width at base of bevel, 13 mm.; thickness at base of tooth, 19.25 mm.; thickness at base of bevel, 7.5 mm.; depth of pulp cavity, 36.5 mm.; weight, 46.5 dwts (troy), or 161 kilogrammes.

Microscopic Structure of the Tooth.—A thin transverse section was taken through the wall of the tooth at the base, bordering the pulp cavity. The intermediate layer is of the nature of ivory like that of the Cachalot,[1] and the outer and inner margins, each about one quarter of the thickness of the middle layer, show the structure of cement. Under a 1-inch objective (about 52 diameters), the cement layer, about 5 mm. in thickness, is homogeneous in structure, but in this specimen is crowded wlith ramulose borings of a parasitic fungus, the hyphal tubes being filled with dark material, probably due to the grinding; isolated spores are also seen here and there.

The intermediate layer, the dentine or ivory, shows a dense structure composed of a closely set series of minute dentinal tubes transversely arranged, whilst circumferentially, or crossing these tubes, are parallel lines of greater density at varying distances, probably contour lines. The intermediate ivory layer in the slide examined measures 2 mm. in width.

1. See Owen. Odontography, 1845, p. 356, pl. lxxxix., fig. 2.

A higher power ($\frac{1}{9}$in. giving 380 diameters) shows the cementum, where not obscured by the hyphae of the boring fungus, to be fairly homogeneous, excepting near the inner dentinal layer, where it is penetrated by the dentinal tubes, which ramble away from their parallel structure in the ivory. The dentinal tubes are crossed by numerous lines of ivory globules and interglobular spaces, probably air-filled. The dentinal tubes are spaced in each optical layer, 15μ apart. The hyphal tubes of the parasitic fungus have an average diameter of 5μ.

Observations.—In the microscopic structure of the above tooth there is sufficient evidence to show its close relationship to the living sperm whale, *Physeter;* but the flattened form of the tooth, which is long—elliptical in section, is a very distinct feature, for only in very extreme examples of that genus can one find a tooth having a broadly elliptical outline. The widely separable forms of tooth base and apex in the two genera are very apparent. In *Physeter* the base is always more or less cylindrical, or even tapering, and the point of the tooth, when depressed, is not hollowed and scalprate as in the above described form.

The heavy, flattened root and moderately deep pulp cavity reminds one of the tooth of *Hoplocetus*, but in that genus the crown is separated from the root by a constriction, and the tooth is fusiform in shape and not wide at the base, and gradually tapering, as in the present form. In reply to a note and sketch of this specimen, which I sent Dr. C. W. Andrews, F.R.S., of the British Museum, he has kindly remarked that it does not agree with *Hoplocetus* as figured by Gervais—whose works, by the way, in the Zoologie et Paléontologie Françaises (vol. I. 1848-52, p. 161) and the Osteographie des Cetacés (p. 345), are not in Melbourne. In view of the fact that the cement layer in this tooth extends over the convex surface almost up to the cutting edge of the apex, there could have been little of the crown exposed, and in view of this character the affinities of the tooth appear to lie with modern sperm whales as *Physeter*.

A rolled and otherwise abraded cetacean tooth figured by E. Ray Lankester in 1867[1] from the Red Crag of Suffolk, may have some generic affinity with the present form. It is stout and fusiform, with a compressed crown, which, so far as the rather obscure sketch shows, is marked with radiating furrows, as in the Table Cape specimen.

1. Trans. Roy. Micr. Soc. Lond., vol. xvi., 1867, pp. 63, 64 (fig. 3).

In the absence of any further evidence as to the relationship of the Tasmanian fossil tooth with already described forms, it is here provisionally referred to a new genus, *Scaptodon.* The stained and fossilised appearance of the tooth leaves no doubt that it was derived from a Tertiary deposit of some considerable age.

Occurrence.—"Found washed up at Ulverstone, N.W. Tasmania, after a heavy gale."—H. H. Scott, Victoria Museum, Launceston, Tasmania. Probably from either Janjukian or Kalimnan beds of the Table Cape series of Tasmania (Miocene or Lower Pliocene).

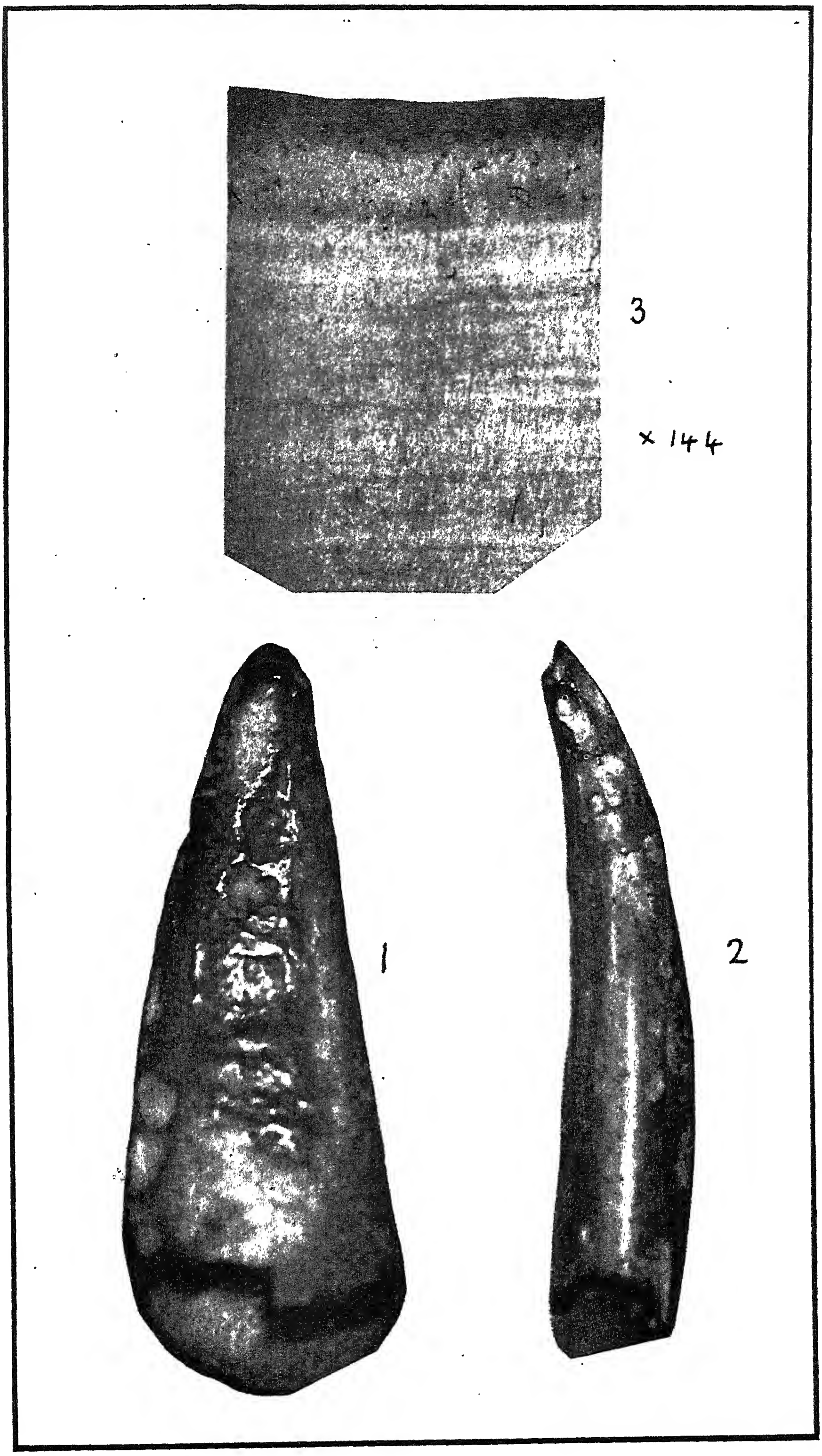
In writing the above I wish to express my thanks to Mr. J. A. Kershaw, F.E.S., for facilities in examining recent specimens, and to Dr. E. Brooke Nicholls, for useful references and suggestions.

EXPLANATION TO PLATE XXVII.

Fig. 1.—*Scaptodon lodderi*, sp. nov. Inner face of tooth. Circ. natural size.

,, 2.—Ditto. Edge view.

,, 3.—Ditto. A thin transverse section of the tooth taken from the base, showing the external cement above and the ivory or dentine beneath. The cementum is perforated by the hyphae of a boring fungus. × 144.



F.C. Photo Tooth of a Fossil Sperm Whale from N.W. Tasmania

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. XV.—*A Contribution to the Theory of Gel Structure.*

BY W. A. OSBORNE, M.B., D.Sc.

(From the Physiological Laboratory, University of Melbourne).

[Read 13th December, 1917].

It is now generally admitted that a gel is a diphasic system, but divergent views are held concerning the nature and possible vectorial characteristic of the more solid phase, and the forces which hold the more liquid phase in position. Whether the meshwork of the more solid phase is composed of micro-crystals, or is truly amorphous, or whether both can give rise to gel structure, further refinements in ultra-microscopy may determine. But whatever view may be correct, the question is unaffected, whether the "filaments," "needles," or micellae assume a definite arrangement under the influence of forces akin to those that produce crystallisation. Is the meshwork of the more solid phase devoid of any vectorial characteristic, or is such actually present?

To throw some light on this problem I commenced certain experiments in 1909 on the shapes of bubbles found in strong gelatine gels when decompressed after being subjected, when warm and during setting, to gas under pressure—generally CO_2. The ordinary fracture of a gel can be described as "perfectly conchoidal," and this in itself indicates that like obsidian or ordinary flint homogeneity of structure may be present. But such reasoning cannot be pushed very far, for conchoidal fracture can be given by crystalline substances, notably quartz. It was this consideration that led me to examine the internal fractures produced by bubble formation. The simplest way to carry out the experiment is to subject warm 10% gelatine solution in a sparklet syphon to the action of CO_2 under pressure. I have also employed the Leonard Hill high pressure chamber with gas pressures of 10-20 atmospheres but the small quantity of gelatine that can be used is here a disadvantage. On decompression the appearance of the jelly is remarkable. Each bubble that forms is lenticular, or apparently a disk of great thinness, and entirely in one plane. I communicated this result to the late Mr. William Sutherland, and he wrote me as follows, under date May 7th, 1910;—

"The form of the gas cavity will depend on the rigidity of the jelly in the following way: The spherical form characteristic of

bubbles in a liquid, when they are small, results from the equality of hydrostatic pressure in all directions. But in a jelly suppose a cavity of any arbitrary shape formed. In the jelly bounding it there will be surface stresses due to the unequal pressure effects of the surface tension acting on parts of the surface of different curvature. If the jelly is weak enough it will begin to flow (like lead in the manufacture of pipes), and will assume finally the spherical form round the cavity. But if the jelly is too strong to flow quickly enough the unequalites of stress will not be relieved rapidly. The escape of gas may accentuate them, with the result that in a stiff enough jelly the material begins to tear at the part of the original arbitrary cavity, where the conditions are most favourable, and the tearing will go on till no longer necessary. A slow flow of the jelly will round off the edges of the spreading cavity, and give it a lenticular shape."

The bubbles make all possible angles with each other, giving a spangled appearance. This point I was particularly anxious to investigate. In a recent number of "Science Progress,"[1] there is a reference to an article by Hatschek in 1914, which apparently dealt with this same subject—the formation of bubbles in jellies. I have been unable through the war to get Hatschek's article in the "Kolloid-Zeitschrift," and so cannot institute any comparison between his results and mine, but most certainly my observations did not support the assumption that any particular angle was predominant amongst these disk-like bubbles. I was at first inclined to regard these results as evidences of the absence of crystalline or pseudo-crystalline arrangement; but as lines of cleavage are absent in certain substances most definitely crystalline, this view can not be rigidly held. If, however, a vectorial characteristic is present, the arrangement must be similar to that exhibited in masonry composed of courses of uniform cubical bricks.

Fracture and Regelation.

If a solid cylinder of 5%-10% gelatine is broken transversely at any point, and the fracture mended by warming the opposing surfaces and allowing to set, it will be generally found that the former line of fracture is the seat of weakness. If a straight piece of combustion tubing filled with 10% jelly is heated between cork guards at some point, and then allowed to stand over-night, it will

1 S. C. Bradford. On the Gelation of the Natural Emulsoids. Science Progress, July, 1917 p. 64.

be found that on expelling the jelly (which can be done with a little practice by quick immersion of the whole tube in warm water) the place of former heating is weak, and fractures readily. Indeed, this region may look to the eye actually thinner. The cause of this is to be found in the well-known hysteresis of jelly. That part which is heated and allowed to reset, will melt more readily on the application of the warmth necessary to loosen the jelly cylinder in the tube. But if a cylinder of jelly is cut through slowly with a platinum wire, carrying an adjustable electric current just sufficient to produce melting of the jelly, a complete transverse lesion can be obtained, which on resetting exhibits no weakness. If an ordered arrangement of the solid phase was pronounced, one would expect to find weakness always manifest, when continuity was once disturbed. No definite conclusion can be based on this evidence, but once more it points either to the lack of any vectorial character or to such being of the nature of a complex of uniform cubical or rectangular units.

The Struve-Baumstark Phenonemon.

In 1885 a method was described by F. Baumstark[1] of preparing aqueous extracts of brain tissue for purpose of analysis. The procedure was simply to immerse the brain matter in ether, whereupon after a day or two a copious watery extract was expelled from the brain tissue, and collected at the bottom of the receptacle. Baumstark found that petroleum ether was without this effect. In reality this phenomenon had been already observed and utilised in 1876 by H. Struve,[2] who investigated the watery extract obtained from various plant and animal tissues. The same device was resorted to by MacMunn[3] in order to obtain muscle extracts for the study of myohaematin.

I have made a number of experiments on this method, chiefly from the standpoint of the structure of gels.

One hundred grms. sheep's brain, immersed in wet ether, gave in three days 37.5 cc. aqueous extract. After one week the amount was 39.9 cc; after three weeks 41.4. The solid matter in this extract was 3.6%.

One hundred grms. of meat fairly fat-free gave in one week 17.5 cc. extract. The solid matter was 4.2%.

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1 Zeit. f. physiol. Chemie. Vol. *9*, p. 145. 1885.
2 Bull. de l'Acad. Imp. de St. Petersburg. Vol. *21*, p. 243. 1876.
Also Bericht. deutsch. chem. Gesell. Vol. *9*, p. 623. 1876.
3 Journal of Physiol. Vol. *8*, p. 54. 1887.

One hundred grms. of the same, finely minced, gave the same amount, namely, 17.5 cc. extract. Solid matter = 4.5%. If brain or muscle be exposed merely to ether vapour, a "sweating" takes place, and drops of extract are formed, but one never obtains anything like the quantity of fluid as when the tissue is immersed in the ether.

Two hundred grms. dry sand in a separating funnel when wetted with tap water retained, after dripping had ceased, 48.5 cc. water.

On pouring ether vapour on the surface of the sand 4 cc. water were immediately discharged below. If the ether vapour is admitted to the under surface only of the sand, this discharge does not take place.

If instead of vapour a quantity of liquid ether is poured on the surface of the wet sand, the following events occur :—At first a few cc's. of water, then a further quick flow of water holding increasing amounts of ether in solution, then ether charged with water, and, lastly, ether with a very small quantity of dissolved water. The sand will now be found to be wet with ether. If petroleum ether is used, then only a small quantity of fluid is very slowly discharged.

A given quantity of sand will hold more tap water than it will water which has been shaken with ether.

It is obvious that we have two effects here. One is the sudden lowering of surface tension due to solution of ether, and consequent fall of the capillary columns of water between the sand grains. If water is allowed to mount up a capillary tube and a small drop of ether is placed in an enlarged part above, but not blocking the lumen, then as soon as the vapour falls down the capillary a rapid drop in the water meniscus can be seen. The other effect is the progressive solution of the ether in the water, the augmentation of the latter in volume and hence progressive discharge until the ether displants the aqueous phase. At the same time there may be diminution of "Haftdruck" in the sense of Traube.[1]

Now coming to gels, we find that some give the Struve-Baumstark reaction, and others do not. Amongst those that display this property in a marked degree are the soaps. A 10% sodium stearate (Merck) gel placed in ether begins to discharge liquid at once. If the fluid is drained off until no more forms, it will be found

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1 Theorie des Haftdruckes, etc. Biochem. Zeit. Vol. 54, p. 305. 1913.

that the liquid phase of the soap gel has been replaced wholly by ether (containing, of course, some water in solution). The gel now exudes ether on compression, and if lit will burn violently. The discharged fluid, however, has some of the solid phase in solution, for it contains more than double the amount of solid matter present in the fluid expressible from the original gel, and moreover, if exposed to the air, and so allowed to lose its dissolved ether, will revert to a moderately firm jelly. Indeed this seems to me to be an ideal method for studying stages of gel formation, as the process can be made slow or rapid as desired. I had at first attributed this partial solution of the solid phase to the presence of alcohol, but repeated washing with water failed to remove this faculty from the ether. The ether layer above the soap jelly in these experiments was found to contain some solid matter in solution, and from the qualitative tests I employed this seemed to be fatty, acid, but I have been unable to pursue this particular investigation.

The discharged fluid will set, therefore, on exposure to the air, and the gel thus formed can be once more subjected to ether; the liquid phase and a portion of the solid dissolved in it will be discharged and the remainder of the solid phase left behind impregnated with ether. This procedure can be repeated three or four times.

The fact that the liquid phase of the soap can be discharged and be replaced by ether is obviously similar to that obtained with wet sand. It certainly indicates that the liquid phase of the soap gel is held by capillarity in the open meshwork of the solid phase.

If, however, a 5% gelatine gel is submitted to ether immersion no fluid, or only an exceedingly small amount is extruded. Whereas a 2% gelatine will show the Struve-Baumstark phenomenon clearly. That there exists a profound physical distinction between these two is evident to the sense of touch alone—the 5% gelatine is dry, the 2% is wet. In the 5%, and in greater concentration, the fluid, we may assume, is not merely held by capillarity, but exists in solid solution in the substance of the framework, whereas in the 2% gel the water-logged lattice holds by capillarity a fluid with a small amount of solid matter in solution. This is at any rate an explanation that falls in with modern physico-chemical theories of gelation. Another possible hypothesis is that the liquid phase in the more rigid gels is formed of small vesicles completely enclosed by walls of solid phase in honey-comb fashion. This explanation is, however, rendered most unlikely by the results of ultra-

microscopic examination.[1] In egg-white coagulated by heat, we have a gel containing some 86% water, but no fluid is extruded when the coagulum is subjected to ether. It is just likely that we have a honey-comb structure here, though the hydrophile nature of the framework may also take its part. On the other hand, the thallus of laminaria, as Struve discovered, exudes fluid copiously. A silicic acid gel containing 13.4% solid matter, though easily fractured, did not give a positive result.

It seems to me, therefore, that the Struve-Baumstark phenomenon can be employed to distinguish those gels where the liquid phase is held, in part at least, by capillarity from those in which the fluid is held, through imbibition, by the hydrophile lattice of the solid phase.

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1 See for instance, W. H. Howell: Structure of the Fibrin-Gel and Theories of Gel Formation. American Journ. of Physiol. Vol. 40, p. 526. 1916.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. XVI.—*On the Formation of "Natural Quarries" in Sub-arid Western Australia.*[1]

BY J. T. JUTSON

(Geological Survey of Western Australia).

(With Plates XXVIII., XXIX.).

[Read December 13th, 1917].

Introductory.

The sub-arid interior of Western Australia possesses many striking surface features, which are as yet but little known, and still less have been the subject of investigation. Amongst minor forms, the remarkable hollows, to which the writer has applied the name, "natural quarries," are worthy of record. They differ in origin from the natural quarries due to ice action; and in normally moist climates they have no definite parallel. Their nearest topographic forms in such climates are certain scars left in places on steep hillsides, owing to land-slips, but for reasons stated below such an origin cannot be postulated for any of the quarries described in this paper.

Summary.

"Natural quarries," in sub-arid Western Australia are of three kinds, circular, rectangular and triangular. They are distinct excavations (resembling artificial quarries) in the hillsides of various rocks; and are chiefly due to the mechanical gouging or undermining action of rain under certain special conditions.

Description.

There are three kinds, broadly speaking, of natural quarries. They may be described as the circular, the rectangular and the triangular types, such terms being based on the kind of plane figure formed by the outline of the quarry on the normal surface slope. There is, however, a certain amount of transition between the different forms.

The Circular Quarry.—This kind forms a more or less circular hole of varying diameter and depth, on a hillside; and in many

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1 By permission of the Director of the Geological Survey of Western Australia.

places has a resemblance to an ordinary shallow artificial quarry excavated in a similar locality. The slope of the hillside is usually steep, or at a moderately high angle from the horizontal. Treating such slope as a plane, the outline of the quarry on such plane would approximate towards a circle, and taking a section down the slope through the quarry, the section line along the plane across the quarry would be the chord, and the outline of the quarry on the section would be the arc, of a vertical circle. In some cases, however, the lowest lip of the quarry may be removed by erosion, and the quarry then passes gradually into the lower slope of the hillside.

The rocks of the hillside are either decomposed igneous rocks, or normal sediments such as shales and grits. The igneous kinds predominate. The rocks must be soft and easily removed, and therefore circular quarries are not found in the unweathered granite and "greenstone." These soft rocks are frequently capped by distinct bands of ironstone, or the surface layers of the rocks may become indurated, without forming a distinct cap. The upper surfaces, therefore, become resistant to erosion. The hard-capped or surface-indurated hills form lines of cliffs, known as "breakaways," connecting a tableland with a lower plain. Small water channels, which are usually mere furrows, one or two feet wide and deep, may lead into the quarry at the top of it, or out of it at its base.

In surface dimensions the quarries range in diameter from a few feet to perhaps 40 or 50 feet, and in depth from perhaps a foot or two to five or six feet. They are generally shallow in proportion to their surface area.

The Rectangular Quarry.—This type is also found on hillsides. Its floor, however, is practically coincident with the floor at the base of, or with the floor of a bench on the hillside. It is different from the circular quarry in that it is bounded by approximately straight lines. Its "back" forms a steep usually vertical, or close to the vertical, plane, which intersects at an acute angle the plane of the hillside. Its floor forms a plane but little inclined from the horizontal, and practically coincident with and forming an extension of the floor at the base of, or of the floor of a bench on the hillside. Thus there is frequently but not always no "front" wall dividing, or partly dividing, the quarry from the adjacent floor; and where a wall does occur it is generally very low and is always broken to allow for the passage of water from the quarry.

The "back" and the floor of the quarry approximate in outline to rectangles, which are frequently at right angles to each other. The two sides of the quarry form triangles on vertical planes, or planes which approximate to the vertical, and which tend to be at right angles to the plane of the "back," The sides of the triangles are therefore formed by the planes of the hillside slope, the "back" and the floor. In the rounding off of corners there is a tendency to destroy the sharp rectilinear outlines, but such outlines are clearly recognisable.

A quarry may form on any hillside provided the rocks underlying the surface rocks are comparatively soft and easily removed. Thus this type of quarry is found on hillsides of soft schistose or stratified rocks, or of any decomposed rocks; and such hillsides may include "dry" lake cliffs. It is not found on slopes with hard granite boulders; but it does occur on slopes littered with small but tough greenstone fragments, for often beneath the surface litter the rock *in situ* may be much decomposed. Rain furrows and small channels may lead to and from the quarry and across its floor. Most quarries are of small dimensions, the average of which for many would be about eight to ten feet high, six to eight feet broad, and ten to twelve feet long. Some quarries greatly exceed these measurements. One on the western shore of Lake Goongarrie, at Comet Vale, is probably 30 to 40 feet high, 40 to 60 feet broad, and 60 to 70 feet long; but this is an exceptionally large one so far as the writer's observations have gone. The figures given are approximate only, as no actual measuring has been done.

The Triangular Quarry.—This type of quarry is more akin to gulches produced by normal erosion at the heads of gullies. On the plane of the slope which it dissects it is roughly triangular, and has the base of the triangle on the upslope and the vertex pointing downhill. It is usually V-shaped in a cross section parallel to the base of the triangle, the sides having but moderate slopes. The "back" however, is somewhat steeper, this feature being accentuated when, as often occurs, a rock cap which tends to be undermined forms the coping to the back. The quarry is mostly connected with a drainage line at the vertex of the triangle, the quarry representing the present but somewhat abnormal head of that line, as the steep slopes and gulches do in an area of normal erosion. Similarly, as in such a normal erosion area, the quarry tends to be at the top of the slope, with its "back" close to the crest line of

the ridge. There is thus a close resemblance between the two types—the quarry under arid, and the steep slopes and gulches under normal, erosion; but marked differences also exist. In normal areas, the lower drainage line or channel is wider and more strongly marked than the upper portion running up towards the crest line, and if the upper portion be branched, the branches are separated by a ridge. In the quarry, however, there is a wide scooping out with no distinct bisecting ridge.[1] Moreover, the quarry is the clearly marked feature, the lower drainage line often being insignificant and difficult to trace by reason of the tendency of the occasional water flows to spread themselves over a comparatively wide belt of the lower country.

The triangular quarries have a moderate range in size. They are from 10 to 15 feet in all dimensions, to a large quarry having a "back" perhaps 100 feet in length measured horizontally along the top. They probably approach equilateral triangles in shape, but the base (the "back") is, the writer believes, usually longer than the sides.

This type of quarry does not, as a rule, form in granite, Much weathered "greenstones" or greenstone schists, with a cap of hard ironstone, appear to be the most suitable rocks for their formation.

Mode of Formation.

The action of the rain in beating upon and undermining decomposed comparatively soft rocks, which are associated in definite ways (to be presently stated) with certain harder rocks, is apparently the main factor in producing the three types of natural quarries above described.

The circular quarry originates in most instances at least in the following way: On the face of a "breakaway," the detritus from the hard surface layers and from the rocks below slowly drift towards the bottom, and in doing so the whole face of the "breakaway" may at any particular period of time be covered with this detritus or talus to a thickness of about one foot or less.[2] Owing to the widespread tendency in sub-arid Western Australia to cement all loose surface deposits by mineralised water rising to the

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1 It must be remembered that these remarks only apply to the triangular natural quarries here described, and that gullies with normal branches in every way similar to those formed in wetter climates are numerous in hilly country in the dry areas.

2 A greater thickness than one foot may occur, but under such conditions it is doubtful if a natural quarry would form.

surface by capillary attraction and by the evaporation of such water with deposition of mineral water, this detritus may be compacted and hardened by the introduction of (chiefly) iron oxide or travertine as a cement. The cemented detritus then forms a cover, fairly strongly resistant to erosion, over the underlying soft rocks. The latter are, therefore, so long as the cover lasts, protected from further erosion. The cover may, however, not be quite continuous everywhere, or it may be very thin and not completely cemented in certain places, or for some other reason a hole in such cover may exist or be made. Having such a hole, the rain may directly beat upon the soft underlying rocks, or may find its way between the cover and the softer rocks, with the result in either case of removing portions of such softer rocks and undermining the cover, which collapses and gradually disintegrates into fine enough material to be carried away by the rain. Once started this process may go on, the hole growing larger until one sufficiently large enough is produced to be called a circular natural quarry. This seems to be the chief method of formation, although some quarries occur which do not seem to have had a distinct cover; but here there is probably some surface hardening of the rocks, without, however, the formation of an appreciable cover. It is also conceivable that some parts of the soft rock are less resistant to erosion than others; that therefore where no cover exists, the beating action of the rain may gouge out the less resistant rocks; and that when once started the cavity so formed may grow in size.

The rectangular quarry in places resembles the scar left by a landslip, but as an accumulation of detritus, such as would result from a rock fall, is never found on the floor of the quarry, this mode of origin must be rejected. It is difficult to account for all quarries of this type, but the following conditions favour their formation :—(1) An abuttal along a vertical or nearly vertical plane of decomposed soft rocks against a band of hard erosion-resisting rocks. (2) Decomposed soft rocks capped by a practically continuous band of loose fragments of a hard erosion-resisting rock derived from an outcrop farther up the hillside. In both cases, if the soft rocks form vertical or nearly vertical schists, the formation of the type of quarry now discussed, is accelerated. The mode of origin is not easy to understand, but it seems that the action of rain beating on the soft rocks is mainly responsible for the wearing away, aided of course by the ordinary weathering agents; and that the resulting form is governed by the band of hard rock or by the surface cover of hard detrital rock mentioned

above, either of these two rock arrangements necessarily tending to produce a steep cliff. It is possible also that water finds its way down through the rocks and oozes out at the base of the cliff, and so may slightly remove, or at any rate weaken the soft rocks at the base of the cliff. When these quarries occur at the edge of "dry" lakes bounded by rocky cliffs the crystallization of salt from water evaporating from the rocks at the base of the cliffs may also help this type of quarry formation, but further investigation is desirable on this point.

The triangular quarries are due to the gouging action of rain on soft rocks. Their form is guided by the hard rocks forming a cap to the "back," which cap resists erosion and brings about the steep "back." At the same time the check given to erosion by such cap causes the denuding agents to follow the line of least resistance, with the result that the quarry is widened between the sides of the triangle, thus causing a lengthening of the "back" along the base of the triangle.

EXPLANATION OF PLATES.

Plate XXVIII.

Fig. A.—Section through a circular quarry. The broken lines indicate the original surface, which has now been removed.

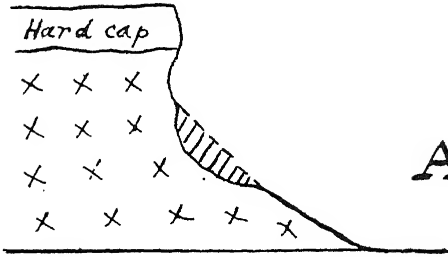
Fig. B.—Block diagram illustrating the formation of a triangular quarry with a hard cap to the "back."

Figs. C. and D.—Sections illustrating the formation of rectangular quarries, the broken lines being the original surfaces, now removed.

Plate XXIX.

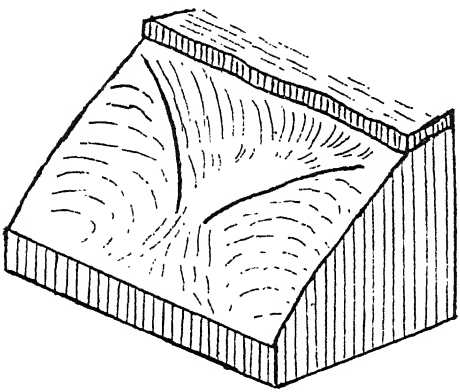
Fig. E.—A circular quarry, Niagara.

Fig. F.—A rectangular quarry, western shore of Lake Goongarrie, Comet Vale.

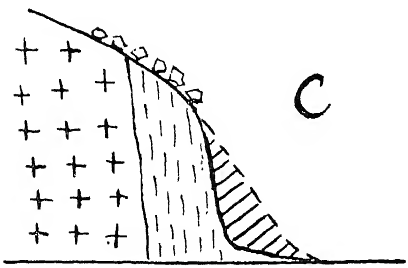


A

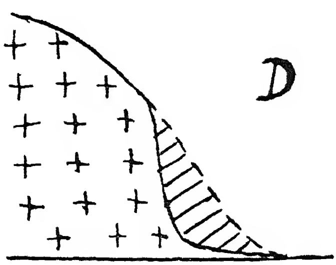
//// Rocks removed to form a circular quarry.



B



C



D

Schistose rocks. Massive rocks.

//// Schistose rocks removed to form rectangular quarries. oo Debris from massive rocks.

Fig. E.

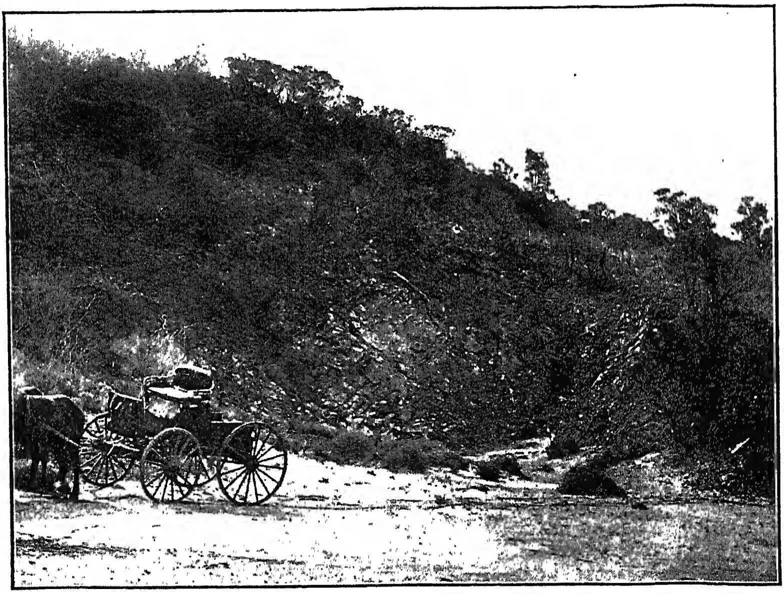


Fig. F.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. XVII.—*The Influence of Salts in Rock Weathering in Sub-arid Western Australia.*[1]

BY J. T. JUTSON.

(Geological Survey of Western Australia).

(With Plate XXX.).

[Read 13th December, 1917].

Introduction.

Among the many erosion processes that are now acting in that portion of sub-arid, south-central Western Australia, which corresponds with the writer's Salt Lake or Central physiographic division,[2] the apparent influence of the crystallization of salts under certain conditions in breaking up the rocks and in assisting to give characteristic forms to certain features of the landscape, has not hitherto been recorded. This phase was first pointed out to the writer at Lake Raeside, which lies chiefly to the east of the railway running north from Kalgoorlie through Menzies and Kookynie,[3] by Professor J. Walther in 1914, on the occasion of the visit to Australia of the members of the British Association for the Advancement of Science. This process of erosion may be regarded as one of the phases of "exsudation," a term which is subsequently defined. Since the visit referred to, the writer has studied the question in the field in several localities, and now submits a brief account of the process and its effect in modifying the land surface.

Situations Favourable for the Work of "Exsudation."

"Exsudation," as understood in this paper, can only be observed taking place in certain comparatively limited situations These are as follow : On the face, but most frequently close to the bottom of the cliffs bounding the "dry" or "salt" lakes; on the rock floors of such lakes; possibly in hollows beneath the hard caps of lines of cliffs known as "breakaways," (which may border

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1 By permission of the Director of the Geological Survey of Western Australia.

2 Jutson, J. T.—*An Outline of the Physiographical Geology (Physiography) of Western Australia.* Bulletin 61 of the Geol. Surv. Western Australia, pp. 32 and 52.

3 Menzies is 80 miles and Kookynie 118 miles north of Kalgoorlie.

or be quite apart from lakes); and possibly on the under surfaces of granite and quartz boulders. The process may be acting on other rock outcrops, but it is probably masked by the stronger erosive action at such other outcrops of other processes, such as insolation and the action of rain.

The Process of "Exsudation" as here Defined.

According to Hume,[1] "exsudation" is a name given by Futterer, and comprises several "desert evaporation effects"; but in this paper the term will be restricted to those processes by which, under certain conditions, flakes or grains are mechanically broken off from the parent rock, or by which the latter, if soft and decomposed, may crumble almost to powder. These results are apparently chiefly due to the crystallization of salts contained in solutions brought to the surface by capillary attraction, and the evaporation there of the water. The deposition of the salts exerts pressure on the rock, with the result that flakes or grains may be forced off or a soft rock may crumble. Walther[2] has described the effect on the rocks in arid areas of the crystallization of salts from evaporating underground water, and a valuable series of observations and experiments as to the disintegration of building stones in Egypt has been made by Lucas,[3] who regards such crystallization of salts as the main agent of such disintegration.

In sub-arid Western Australia, the operation of "exsudation" is best seen in cliffs—usually at or close to the base of such cliffs—of weather-resisting rocks, at the edge of a "dry" lake. Amongst the resistant rocks forming these cliffs the "greenstones" are the most abundant; and such cliffs are frequently high, steep and prominent features on the borders of the lakes. "Hard," practically undecomposed granite also occurs, but the cliffs so far seen by the writer are usually low and insignificant.

These rocky cliffs frequently rise from a rock floor at the edge of the lake of such an extremely smooth level character that the writer has applied to such a floor the name "billiard-table rock-floor." The cliffs may be nearly vertical for some height, ranging from a few feet to perhaps 20 feet, beyond which they recede at

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1 Hume, W. F.—*Professor Walther's Erosion in the Desert considered.* Geol. Mag. Decade VI., vol. i. (1914), p. 19.

2 Walther, J.—*Das Gesetz der Wüstenbildung.* 2 ed., Leipzig, 1912, pp. 128-129.

3 Lucas, A.—*The Disintegration of Building Stones in Egypt.* Survey Department, Cairo, 1902.

either a high or a moderate angle from the horizontal; or such approximate verticality may not exist in any portion of the cliffs. The base of the cliffs is, in various localities, undermined into irregular caves and hollows varying both in breadth and height from a foot or two to several feet, but the floors of the caves and hollows are not always coincident with the lake floors, although frequently they are so. The caves and hollows in places increase in height away from the cliff face, that is, the roofs become more dome-like. This doming is helped by the tendency to form resistant films on the outside surfaces of the rocks; and in its results resembles to some extent the "pocket rock" and the effects partly due to "shadow-weathering" of other areas, referred to by Hobbs.[1]

The undermining may be more or less continuous along the base of the cliffs for some yards; and where strong vertical joints or other division planes occur, a roughly rectangular outline may be given to the part attacked.

The roofs, sides and floors may be damp, and the roofs and sides have a very scaly appearance owing to innumerable thin rock-flakes (of from one-half to two inches in length and breadth, and usually from one-eighth to one-quarter of an inch in thickness) being shed from the parent rock. On account of their thinness and of their decay during the process of splitting off, these flakes can usually be broken by the fingers. This flaking is, in the writer's opinion, chiefly due to the process of "exsudation," which has been defined above.

Meteoric water percolating from the surface downward must assist "exsudation" by acting as a solvent, however slight or slow, thereby weakening the rocks and making them more liable to further decay. This water also, by passing down joint planes and dripping on to the floors of the caves and hollows, helps to enlarge such hollows, one mode of such enlargement that has been noticed being the scooping out of small lens-shaped hollows in uneven floors along joints.

The rocks at the base of the cliffs must, by reason of the constant drawing up of moisture by capillary attraction, aided by the downward percolation of surface waters, be mostly in a more or less soaked state, which must undoubtedly tend to make the rocks less coherent.

In many places the sun's rays never reach the sides and roofs of the cavities, so that temperature variations must be negligible in

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1 Hobbs, W. H.—*Earth Features and their Meaning.* New York, 1912, pp. 201-206.

their effect on the disintegration of the rocks. The direct action of rain must also be excluded, as it cannot beat on to many sides and roofs. Similarly the wind must take little part in the actual breaking up of the rock; and as regards the lake waters as abrading agents, the lakes are dry, especially at the edges, for very long periods; and the water in the lakes is, as a rule, not more than a few inches deep.[1] No normal waterworn pebbles are found, and the only conclusion appears to be that the lake waters have no abrasive power.

The rock flakes further break up on the floor of the caves, and in time the debris is removed, mainly, in the writer's opinion, by deflation, but discussion of this aspect does not come within the scope of this paper.

Cavities are sometimes scooped out on the face of a cliff at any height from the ground up to perhaps 20 feet, but the hollowing out is chiefly confined to a band rising from the lake floor to a height of about four feet; and where the undermining takes place regularly over a length of some yards, the cliff may, in a very marked way, overhang a regularly hollowed out area, which is about two feet high from the lake floor upwards, one to two feet broad, and several yards in length along the line of junction of the lake floor with the cliff. Lucas[2] has noted that in the decay of building stones in Egypt the action is frequently limited to a metre or a metre and a half above the ground level; or if not actually limited to that extent, it is usually greatest at or near the surface of the ground; and his conclusion is that the disintegration is chiefly due to the crystallization of salts by the evaporation of water on the rock surface, that is the process now under description.

White incrustations or efflorescences occur frequently, but not always, on the Egyptian rocks, which are subject to the process described. In Western Australia no pronounced efflorescences at the lake cliff cavities have been noted by the writer. This is a point requiring further investigation.

The ground water is usually close to the lake floors, and is very saline. The following are two analyses, made in the Western Australian Geological Survey Laboratory, of waters, one of which was collected from a trench sunk on Lake Cowan, Norseman,[3] and the

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1 The writer has been informed that water, 10 feet or more deep, has been observed in a lake; but if so, it is quite exceptional and perhaps due to some artificial embankment. Most observers agree that the lake waters are generally not more than a few inches deep.

2 Op. cit., p. 3.

3 Norseman is 108 miles south-south-east of Coolgardie.

other from the Happy Jack Mine at Comet Vale,[1] the mine being west of Lake Goongarrie, and about three-quarters of a mile distant from the lake's nearest point.

Salts.		Parts per cent. Happy Jack Gold Mine, Comet Vale.		Lake Cowan, Norseman.
$CaCO_3$	-	.0023	-	.0076
$CaSO_4$	-	.1328	-	.2238
$MgSO_4$	-	2.1532	-	1.1324
$MgCl_2$	-	2.9943	-	3.1905
KCl	-	.0378	-	.0738
NaCl.	-	20.1071	-	18.8806
$NaNO_3$	-	nil.	-	...
NaBr	-	nil.	-	...
NaI	-	nil.	-	...
$Al_2O_3.(Fe_2O_3)$	-	.0200	-	.0044
SiO_2	-	.0100	-	trace
Total solids	-	25.4575	-	23.5131
Extra CO_2	-	.0030		
Analyst		D. G. Murray		E. S. Simpson.

The predominance of common salt may be noted.

The Happy Jack water is extremely salt for a water away from a lake, but it shows how salt some of the underground waters are. In its percentage and nature of solids, it is probably close to the normal underground lake waters. These analyses show that there are abundant salts to operate on the rocks in the way described.

Space does not permit of detailed descriptions of particular localities where the features described above may be seen, but as examples of the flaking of hard greenstone rocks, reference is made to the western shore of Lake Goongarrie, at the eastern end of the "peninsula," between Comet Vale and Goongarrie.[2] An example of flaking of practically undecomposed granite occurs at the low cliffs at the western end of an unnamed and unmapped lake to the east of the north-eastern corner of Lake Goongarrie. The rectangular outlines of some of the undermined cavities, which are largely due to vertical joints and other division planes, may be seen at the extremity of the peninsula at Lake Goongarrie.

1 Comet Vale is 63 miles north of Kalgoorlie,

2 Goongarrie is 55 miles north of Kalgoorlie.

All greenstone cliffs bordering lakes have not pronounced caves and hollows at their base; but some hollowing out, although perhaps only a small scale, can generally be detected. If the rocks are comparatively soft or finely schistose, the rate of ordinary weathering on the face of the cliff by insolation and the action of rain, may keep pace with or exceed the rate of weathering at the base, with the result that no pronounced hollows or caves are formed; and the angle of slope of the cliff will depend on the ratio between the two forces. The prominent greenstone cliffs on the western shore of Lake Goongarrie, close to the town of Comet Vale, afford excellent illustrations of fairly steep slopes with practically no hollows at the base. Here the respective rates of erosion at the base and on the upper portion of the cliff appear to be about equal.

The writer believes that "exsudation" also acts to some extent away from the lakes in the hollowing out of granite boulders, and in the formation of caves and hollows beneath the hard caps of the lines of cliffs known as "breakaways." It is proposed, however, to discuss these questions in another paper.

Rock floors are exposed—or coated with mere films of silt—in at least portions of many lakes. The rocks may be ancient sediments or igneous rocks, and are frequently "soft" and easily broken. When the floor is free from surface water, the underground water is drawn to the surface by capillary attraction, evaporation takes place, and an efflorescence of salts (chiefly common salt) occurs on or near the surface of the rocks. The surface of the latter tends to break down into a meal, which is soon swept away by wind or water. The writer has collected numerous specimens of these rocks, which showed little salt deposited on the surface, but which must have contained in solution a comparatively large amount, as after a few days common salt was thickly deposited as an efflorescence, and some specimens had crumbled to pieces. On these rock floors, exposed as they are for the greater part of the year to the sun's rays, the amount of direct and indirect disintegration by salt efflorescence is probably considerable, and an appreciable factor in the general erosion of the land.

The Results of the Process.

The results of the process of "exsudation" as here considered, aided by other apparently subordinate processes, have already been partly stated. They may, however, be now briefly summarised. They include:

(1) The hollowing out of cliffs of hard rocks abutting the "dry" lakes, generally at or close to the base of such cliffs, thereby tending to keep the cliffs steep, and at the same time assist in their recession; and by such hollowing to aid in forming level rock floors at the edge of the lake.

(2) The disintegration on rock floors of lakes, whether close to or at any distance from the cliffs, of the rocks forming such floors.

Further research, particularly on the chemical side, is needed to definitely substantiate these results.

The mode in which the debris at the foot of and beneath the cliffs, and on the rock floors of the lakes, is removed, does not come within the scope of this paper; but in order to fully understand the part played by "exsudation," brief mention must be made of the processes following the breaking down of the rocks, and the effect on the land forms.

As already pointed out, the cliffs are broken down by rain, by insolation and by "exsudation," these agents being helped by the weakening of the rocks by meteoric waters acting as solvents. The removal of the detritus is, in the opinion of the writer, chiefly due to the wind acting in its deflative capacity, although the lapping of the lake waters, when they collect after rain for a brief period, may remove fine material in suspension, but this removal is often counterbalanced by the deposition of the silt when the water disappears. On the rock floors of the lakes the same principles apply. The wind as a corrosive agent is also believed to act on the base of the cliffs, and on the rock floors to some extent.

The effect of such processes is to produce a cliff of varying steepness, with a rock floor of such smoothness that the writer has termed it a "billiard-table rock floor." The cliff recedes, and, owing to various causes, is followed by the water. Thus a migration of the lake takes place.[1] Such migration of cliffs and of lakes, and the production of level rock floors, are materially aiding the formation of a vast plain at a considerable height above sea level as opposed to a normal peneplain, whose base level approximates to that of the sea.

ADDENDUM.

Since this paper was read, Mr. F. Chapman, A.L.S., etc., of the National Museum, Melbourne, has kindly drawn the writer's attention to an interesting letter by Dr. F. A. Bather on salt weathering, in the

1 The theory of lake migration in Western Australia has been first stated by the writer in his work already cited (pp. 155-57), and has been elaborated by him in a hitherto unpublished paper.

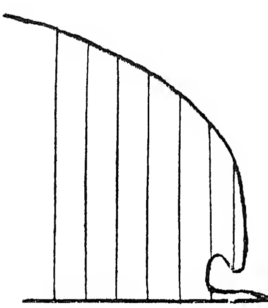
"Geological Magazine" for November, 1917, pp. 526-528, in which is raised the question of the chemical action of sodium chloride in addition to the mechanical principle of crystallization. In this connection Dr. Bather refers to the work of Professor R. C. Wallace, whose full statement will be awaited with interest.

EXPLANATION OF PLATE XXX.

Figs. G. and H.—Sections illustrating undermining of rock cliffs on shores of "dry" lakes. In *G* the small cavity may be regularly continuous for some yards along the line of cliff.

Fig. I.—Undermining of granite on the western shore of a lake, east of Lake Goongarrie, Comet Vale district. The rock floor is not visible here.

Fig. J.—Undermining and hollowing out of greenstone cliffs at the "Peninsula," Lake Goongarrie. A thin layer of silt covers the rock floor here.



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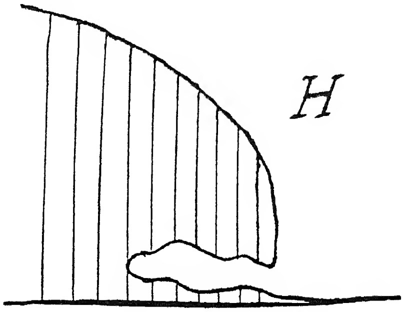

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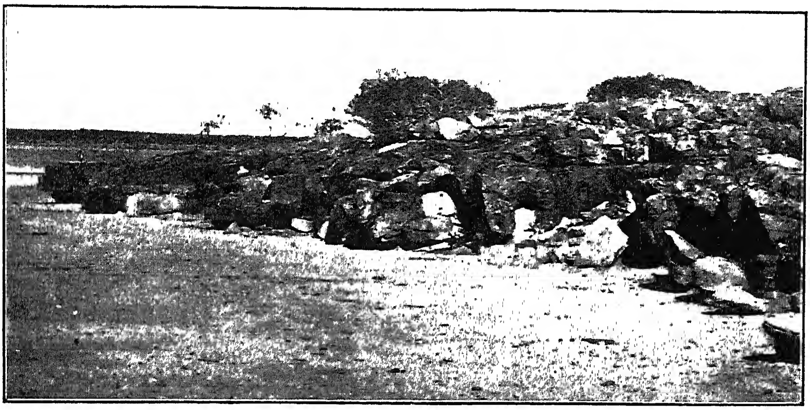

Fig. 1.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. XVIII.—*Contributions to the Flora of Australia, No. 26.*[1]

BY

ALFRED J. EWART, D.SC., PH.D.

(Government Botanist of Victoria, and Professor of Botany and Plant Physiology in the Melbourne University).

[Read 13th December, 1918].

ACACIA GLANDULICARPA, F.M.Reader. (Leguminosae). "Hairy Pod Acacia."

Whipstick Forest, near Bendigo. Collector, David J. Paton, September, 1917. A native of Victoria, previously only recorded from the Mallee.

CYNOSURUS ECHINATUS, L. (Gramineae). "Rough Dog's Tail Grass."

Mentone, Collector, J. R. Tovey, December, 1916, Ferguson, near Beech Forest. J. Murchison, February, 1917. New localities in Victoria for this introduced grass, which has previously been recorded from the Drouin district only.

CROWEA EXALATA, F. v. M. (Rutaceae). "Crowea."

Whipstick Forest, near Bendigo, D. J. Paton, December, 1916. This is a new locality in Victoria for this plant. It had previously been recorded from the east and north-eastern localities only.

Mr. Paton says that the plant is fairly abundant in the Whipstick Forest, in two or three localities, notably near Eaglehawk, whence the present specimens are taken. It seems to be associated with the Mallee-like flora of the Whipstick, as I have not observed it on the southern side of Bendigo, where the flora is of a different type. As found here it is a low erect or straggling shrub, seldom attaining three feet in height, and often much less. November and December is the best flowering period, though a few flowers may be gathered at almost any season of the year.

1 No. 25 in Proc. Roy. Soc. Victoria, 1917, vol. xxix. (n.s.), pt. ii., p. 142.

Drakaea Huntiana, F. v. M. (Orchidaceae). "Tiny Hammer Orchid."

Cravensville, R. S. Rogers, December, 1917. A new record for Victoria of this rare orchid, which was first described from specimens found on Tingiringi mountain, New South Wales, in 1889, by Bauerlen.

Erica arborea, L. "Tree Heath." (Ericaceae).

Selby, C. French, junr., October, 1917.

Becoming very common along the Gembrook line. It was first recorded at Wheeler's Hill (J. W. Audas), and Beaconsfield (Mrs. Dancocks), and must now be regarded as definitely naturalised. The plant has no injurious properties, and is a decorative shrub, which has escaped from gardens. As Epacrideae in Victoria take the place of Ericaceae in England, it will be of interest to see to what extent this introduced Erica will oust the native Epacrideae.

Hypericum tetrapterum, Fries. (Hypericineae).

Government House Domain, Melbourne, P. F. Morris, January, 1917.

This plant, a close relative of the St. John's Wort, is a native of Europe and North Asia, may be classed as an exotic not yet sufficiently established to be considered naturalised.

Inula graveolens, Desf. "Stinkwort." (Compositae).

Tyabb, Victoria, A. S. Krcrouse, May, 1917.

This plant, which is proclaimed under the Thistle Act for the whole State, is now evidently spreading in the above district.

Lactuca scariola, L. "Prickly Lettuce." (Compositae).

Near Deniliquin, N.S.W., per Mercantile Land and Finance Co. Ltd., April, 1917.

A native of Europe and Central Asia. It is an annual or biennial weed of no economic value, and apt to be spread readily by seed. Sheep will eat it down, particularly when it is young. This plant was recorded as a naturalised alien in the northen parts of Victoria in 1913, and is now evidently spreading in New South Wales.

LEPIDIUM VIRGINICUM, L. (Cruciferae). "Virginian or Wild Peppercress."

Mt. Wycheproof, Rev. W. W. Watts, November, 1916.

A new locality for this introduced plant. It is a native of North America.

LOBELIA ERINUS, var. GRACILIS, L. (Campanulaceae) (Lobeliaceae). "Prickly Lobelia."

Scrub near Lake Margaret Power station, Tasmania, T. B. Moore, January, 1917.

This handsome Lobelia is already a naturalised alien in Victoria, and may also become a naturalised alien in Tasmania.

LORANTHUS PENDULUS, Sieber. (Loranthaceae). "Hanging Mistletoe."

Diamond Creek, C. French, junr.

Growing in fair abundance on such introduced plants as Robinia pseudacacia and Cytisus proliferus. Other instances of the spread of native mistletoes to introduced trees have already been recorded.

LYCHNIS CORONARIA, Desr. (Caryophyllaceae). "Rose Campion."

Anderson's Creek, Hazeldene, 29/1/1917, J. W. Audas.

Spreading rapidly in this locality. A native of South Europe and Asia Minor.

MESEMBRYANTHEMUM LAXUM, Haw. "Loose-flowered Pigs-face." (Ficoideae).

Burwood, J. W. Audas, 17/8/1917. Growing in fallowed land and in process of naturalisation.

PARONYCHIA CHILENSIS, D.C. "Chilian Whitlow Wort." (Caryophyllaceae) (sub order, Illecebraceae).

Moonee Ponds, J. P. McLennan, 1909. Eldorado, H .B. Williamson, No. 1454. Werribee River, C. French, junr, January, 1917. Near Diggers' Rest, C. French, junr., May, 1917.

This plant, a native of Chile, may now be considered to be established as a naturalised alien in this State.

PHALARIS PARADOXA, L. (Gramineae).

Menindie, N.S.W., November, 1916.

A new locality for this introduced plant. It is a native of the Mediterranean Regions.

ROSA RUBIGINOSA, L. (Rosaceae). "Sweet Briar."

In a tall old plant, 6 ft. high, the tap root was found to have descended 3 ft. in sandy soil, while the largest lateral root extended 6 ft. 6 in., at an average depth of over 2 ft. In the case of this plant, after cutting the stem nine inches below the surface, new shoots appeared above the ground. Usually, however, lateral shoots only arise from the stock a few inches below the ground, and with such young plants a six inch ploughing usually cuts away the roots capable of growth, those left in the ground dying. When the ground is moist and the plants are dragged out with a horse and chain, there is a greater possibility of leaving behind parts capable of developing new shoots, but these can be easily destroyed with a mattock when they appear a few months later.

SISYMBRIUM ORIENTALE, L. (Cruciferae). "Indian Hedge Mustard."

Foreshore, Geelong, H. B. Williamson, No. 1449, December, 1910. Northcote, W. R. A. Baker, January, 1911. Bank of Yarra, Anderson Street Bridge, W. R. A. Baker, January, 1913. Warracknabeal, E. T. Lukey, November, 1913.

It is a native of Europe and Asia, now widely spread in Victoria. This plant is very easily confused with Erysimum repandum, and in some cases records of E. repandum really refer to Sisymbrium orientale. It is a weed of waste places, but spreads in pastures and cultivated ground if neglected.

SOLANUM HETERANDRUM, Pursh. (Solanaceae). "Pincushion Nightshade."

Bute, S. Australia, per Professor Osborn, March, 1917. This North American weed is already recorded as a naturalised alien in Victoria and New South Wales, and is now evidently establishing itself in South Australia.

STATICE THOUINI, Vis. "Thouin's Sea Lavender."

A garden escape at Wycheproof.

A native of the Mediterranean Regions. Coll., Rev. W. W. Watts, Dec., 1916.

ULEX EUROPAEUS, L. (Leguminosae). "Furze or Gorse."

An important factor in determining the persistence of perennial weeds during dry summers is the depth to which the roots penetrate. Nevertheless, in the case of gorse, the plant seems to withstand dry seasons, even when the roots penetrate only to a small depth. Thus in one case a green clump four to five years old, 2 ft. 6 in. in height and 4 ft. across, was growing on thin soil, with a hard pan subsoil which the roots were unable to penetrate. Their depth varied from 4½ to 6 in., without the plant appearing to suffer from the dry summer. On looser soils the roots penetrate much more deeply. The deepest roots were found on a loose soil, with a porous clay sub-soil, in which they attained a depth of 2 ft. 7 in. Under still more favourable circumstances possibly greater depths may be obtained.

XANTHORRHOEA AUSTRALIS, R.Br. (Liliaceae). "Grass Tree."

In addition to the resin produced by this plant other products may be obtained from it, some of which may have an economic value. By distilling the resinous leaf bases with water, Mr. Watt, of Cobden, obtained a dark coloured, strongly smelling grass tree oil, which if it could be obtained cheaply and in abundance might be of some value as an insecticide. The oil itself killed every leaf to which it was applied, viz., grasses, St. John's Wort, sunflower, dahlia and onion weed. Unfortunately the oil does not mix with water, and although water shaken up with it acquires a strong smell of the oil, it had no effect when sprayed on plants of St. John's Wort, and also did not affect the grass leaves around them.

[PROC. ROY. SOC. VICTORIA, 30 (N.S.), PT. II., 1918].

ART. XIX.—*On Chlorophyll, Carotin and Xanthophyll, and on the Production of Sugar from Formaldehyde.*

BY ALFRED J. EWART, D.Sc., PH.D.

(Professor of Botany and Plant Physiology in the Melbourne University and Government Botanist).

[Read 13th December, 1917].

In a previous paper the theory was put forward that the production of carbohydrates in plants did not take place by a direct synthesis of carbon dioxide and water to form formaldehyde, and then sugars by polymerization, but that the carbon dioxide and water combined with the phytyl base of chlorophyll to form xanthophyll or carotin, and that this by photo-oxidation produced formaldehyde, reducing sugar and phytyl, the latter recombining with the chlorophyll molecule. This would represent a change in which chlorophyll played the part of an enzyme, requiring a supply of energy in the form of light for its activity. This conclusion was mainly based upon the facts that formaldehyde is produced by the photo-oxidation of chlorophyll films in the presence or absence of carbon dioxide, and that chlorophyll films in contact with water saturated with carbon dioxide turn first yellow and then brownish white, slowly in darkness and rapidly in light, while at the same time they appeared to gain in weight and did not set free any oxygen.

In the earlier work I was able to extract small amounts of xanthophyll from chlorophyll films decomposed by carbon dioxide by treatment with potash and extraction with alcohol and separation with ether. Hence the conclusion was made that an actual production of xanthophyll had taken place. Jürgensen and Kidd[1] suggest, however, that the chlorophyll films used might have contained xanthophyll as an impurity, and they confirm Willstätter's[2] statement that the action of carbon dioxide on chlorophyll is due to its removing magnesium, and converting the chlorophyll into phaeophytin, which in the form of films is yellow in colour.

On using chlorophyll separted from 80 per cent. acetone by petrol ether, and removed from the latter, after washing, by the

1 Proc. Roy. Soc., January, 1917, p. 342.

2 Sitzungsb. d. Kgl. Press. Akad. der Wiss, 1915, pp. 322, 544.

addition of talc and filtering, no xanthophyll could be extracted from the films decomposed by carbon dioxide.

Nevertheless, that the first stage in photo-synthesis might be a direct addition synthesis with carbon dioxide is by no means impossible. It has long been known that direct addition syntheses of carbon dioxide can be produced with the aid of strong reducing agents such as sodium or potassium (Wanklyn, Kolbe), Bremmer (Annalen, 350, 1906, p. 313) has shown that hydroquinone heated with potassium carbonate, bicarbonate, glycerine and sodium sulphate in a stream of carbon dioxide yields oxysalicylic acid and dicarboxylic acid ($C_8H_6O_6$). Similar results were obtained with phenol and resorcin, while gallic acid yielded a gallocarboxylic acid. Presumably phenols may be transformed into Ketone combinations with a free affinity to which carbon dioxide can attach itself, that is a direct addition synthesis with carbon dioxide takes place.

The action of watery solutions of carbon dioxide on chlorophyll in light and in darkness.

Pure dry carbon dioxide does not appear to exercise any action upon chlorophyll films in darkness, or even in light, after several weeks' exposure the films being still green and not appreciably altered. As the presence of water is necessary, a large bulb tube was lined with chlorophyll half way from the bulb end. The tube was filled with pure carbon dioxide over mercury, and after introducing 0.5 c.c. of water saturated with carbon dioxide, was exposed to light for three weeks. The films were still green, but with a yellow tinge. The weight of chlorophyll used was 0.216 gram. Out of 2440 c.c. of carbon dioxide 15.6 c.c. disappeared, and the residual gas contained 0.4% of nitrogen, but no oxyyen. Apparently a rapid reaction between chlorophyll and carbon dioxide only takes place when the former is in direct contact with a watery solution of the latter.

Repeating the experiment with a tube containing sufficient water to cover the film, the upper end being drawn out, sealed, and the tube exposed for one week, the water became pale yellow, and the chlorophyll yellowish green. Eight c.c. of saturated water were used, 40 c.c. of carbon dioxide and 0.22 gram of chlorophyll. After bringing the whole tube to the original temperature, and allowing for the pressure, the gas had decreased in volume only 3.8 c.c. (i.e., 0.007 gram CO_2 per 0.006 gram of Magnesium). On evaporating the water to dryness, and adding the chlorophyll film

after dissolving it in hot alcohol, the total weight of residue was 0.21 gram, i.e., a slight loss instead of a gain.

In the experiments mentioned in the previous paper in which chlorophyll films appeared to gain in weight after exposure to light in water saturated with carbon dioxide, the films were weighed in situ in the tube after pouring off the water and drying in a current of rarified dry air at room temperature. Repeating a similar experiment, a film weighing 0.105 gram appeared to increase in weight to 0.228 gram. Close observation showed, however, that dry chlorophyll films in water swell and imbibe water, and that this water is not removed wholly by drying at room temperature, the films assuming an approximately constant weight while still containing a large percentage of water. The same film on dissolving in alcohol and petrol ether weighed on drying 0.102 gram.

On the other hand, if dried in air at 50°C. or 60°C., the films lose weight by oxidation. In one test experiment this loss amounted to 3% in ten hours. In a second experiment a dry film weighing 0.264 gram, weighed 0.251 gram after sixteen hours at 60° in air and darkness, and 0.234 gram after forty hours, being then quite yellow with nearly all the green colour lost. This error can be avoided by drying in *vacuo*, or in hydrogen or nitrogen. In a further experiment conducted with every possible precaution, a chlorophyll film weighing 0.228 gram after one week's exposure to light in water saturated with carbon dioxide weighed 0.223 gram, i.e., it lost slightly instead of gaining in weight.

The film is, however, not wholly insoluble, but a little matter passes into solution in the water, and this may include one product, formaldehyde, which is mostly lost on evaporation.

Experiments on a large scale were then carried out by using ordinary sparklet syphons. Dry chlorophyll, obtained by petrol ether separation from an acetone extract and subsequent purification, was weighed in a small beaker, dissolved in a little ether, poured into the syphon, and the beaker then dried and reweighed. A current of warm air was passed through the syphon, which was inclined and revolved until an even chlorophyll film formed up to the danger mark. The syphon was then filled to this level with cold boiled water, the head screwed on a sparklet bulb attached, and after previous exhaustion by a Geryck pump while in the inverted position, the bulb was pierced, and the water charged highly with carbon dioxide. One syphon was exposed to sunlight for a week, the other left in darkness. Owing to the sunlight warming

and partially melting the chlorophyll, the film sometimes becomes more or less distorted. This can largely be avoided by keeping the syphon under cold water flowing from a tap. The syphons remained highly charged with carbon dioxide, but contained no oxygen.

The films on washing with absolute alcohol gave a yellow solution containing phaeophytin and turning green with zinc acetate. The water was also evaporated to dryness. It was at first clear and colourless, but became faintly brown on evaporating. A trace of solid residue was left by the water from both syphons, which was partly soluble and partly insoluble in water. It averaged under 2% of the weight of chlorophyll used.

If the films are prepared from the first petrol ether separation of chlorophyll without further purification, the water always leaves a larger residue, and that from the syphon exposed to sunlight always contains some reducing sugar. Thus, in one case, the water from the syphon in darkness left a residue containing a little matter soluble in water, and giving a trace of reduction by Fehling's test, and a brownish white waxy solid soluble in petrol ether. The residue from the syphon in sunlight contained more matter soluble in water, and gave a strong reduction with Fehling's test. Further tests showed a hexose sugar to be present. The weights were in grams.

	Sunlight.	Darkness.
Chlorophyll film	0.359	0.37
After 1 week in water + CO_2 under pressure	0.265	0.306
Residue from evaporation of water	0.056	0.039
Total Residue	0.321	0.345

The same experiment was repeated, using thicker films of chlorophyll, exposures of four weeks' duration, and evaporating the large bulk of water under reduced pressure and temperature. The water from the sunlight syphon left a brown residue on the sides of the vessel on evaporating, and a gummy residue on the bottom. More than half of the residue was soluble, and it gave the tests for a reducing hexose sugar. The water from the syphon in darkness left a brown non-gummy residue of which less than 1/5 was soluble in water, and gave a white flocculent precipitate with Fehling's test, but no reduction. No trace of free oxygen was found.

For demonstration purposes the syphon can be filled half way above the danger mark and then charged with a sparklet, using a control without carbon dioxide. After a week in darkness a comparison of the two syphons forms an admirable lecture demonstration of the action of a solution of carbon dioxide on chlorophyll, the film in the first case being yellow, in the latter, green.

The film from sunlight was in the thinner parts nearly colourless, and in the thicker parts more brown than yellow. It contained less phaeophytin than the films kept in darkness. The weights were—

	Sunlight. grammes.		Darkness. grammes.
Chlorophyll film - - - - - - -	0.555	-	0.527
Total film residue after 4 weeks - - -	0.301	-	0.458
Total water residue - - - - - -	0.205	-	0.058
Total -	0.506	-	0.516

From the above it would appear that in sunlight and CO_2, chlorophyll decomposes slightly more than in darkness, that a little formaldehyde or other volatile product is formed, and that if any oxygen is formed, it is not set free, but oxidises the phaeophytin. The action is not continuous as in the plant, since there is no reconstruction of the chlorophyll.

It appears, further, that the sugar formed in the plant remains at first in loose combination with the chlorophyll, and follows it into the petrol ether and other solvents, and that it is only separated from the chlorophyll when this is purified by precipitation.

If pure chlorophyll films are dusted over with zinc dust, they remain green in contact with a solution of carbon dioxide in water indefinitely, and even after a week's exposure to sunlight only show a slight fading on the more exposed side. On dissolving the films the solution shows the same absorption bands as chlorophyll, but the solubility is altered.

On incinerating, the ash of the green pigment was found to consist of zinc oxide, and not of magnesium oxide. It evidently consisted of the salt of zinc with phacophytin, described by Willstätter and Hocheder (Annalen der Chemie, 1907, 353, p. 205), which closely resembles chlorophyll. Evidently in the presence of a saturated solution of carbon dioxide in water, zinc will displace the magnesium of chlorophyll. In the previous paper I had described some results which seemed to show that with the aid of zinc dust and in the presence of carbon dioxide a reconstitution of chlorophyll was possible from the products of its decomposition. What really happened was that the zinc salt of phaeophytin was formed, which closely resembles chlorophyll, and is easily mistaken for it. This zinc salt appears to be more resistant to acids and to photo.-oxidation, and to be more stable than natural chlorophyll.

It is worthy of note that impure chlorophyll films prepared directly from the first petrol ether separation of an alcoholic

extract of chlorophyll always bleach more rapidly in light than do pure preparations of chlorophyll. No evidence could be obtained of the existence of any special oxidase enzymes in the impure films, but these always yield small amounts of reducing hexose sugar, even if previously well washed with water prior to photo-oxidation, whereas fully purified chlorophyll yields no sugar on photo -oxidation. In one test experiment, a sample of pure chlorophyll was prepared as described by Willstatter and Hüg (Annalen, 1911, p. 177). Two films of it were prepared each in a large bulb tube, containing dry CO_2 free air. After a week's exposure to sunlight, no further bleaching took place. The volume of air decreased by 14.6%, a small amount of water appeared, but no reducing sugar. After shaking with water and filtering, the latter gave Riminis, Schryver's, Schiff test, and the Schiff and sulphuric acid tests for formaldehyde. The amount present was, however, distinctly less than when a current of air was passed over long tubular films exposed to sunlight, and then led into water, as described in the previous paper.

The changes which chlorophyll undergoes during photo-oxidation in dead tissues are not necessarily precisely similar to those taking place after its extraction and purification. It has, however already been shown (Proc. Royal Society B., 1908, 80, 30) that formaldehyde is produced in green leaves by the photo.-oxidation of chlorophyll after death, and in the absence of carbon dioxide.[1] Green grass leaves were boiled and then dried in a strong press repeatedly until they yielded no trace of reducing sugar. The leaves were then spread flat on glass plates, and held in position by silk threads. The plates were placed in large glass vessels—(a) containing CO_2 free air, (b) with CO_2 present, (c) ordinary air. The vessels (a) and (b) were exposed to sunlight until the leaves were bleached, (c) was kept in darkness. The air in all three was kept moist. The leaves were then extracted with boiling water, which was concentrated, filtered and tested. Both (a) and (b) yielded small amounts of reducing hexose sugar, while (c) yielded none. Apparently the post mortem photo-oxidation of chlorophyll and its companion substances can increase the extractable sugar content of drying hay in the same way that photo-oxidation causes sugar to separate from an impure chlorophyll film.

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1 Further confirmation of this has recently been given by Osterhout, see n. ser. 42, 1915, p. 68. See also Schryver, Proc. Roy. Soc. London, B., 1910, 82, 226.

The influence of temperature.

Thin, bright green chlorophyll films formed on the floor of a beaker kept on a boiling water bath rapidly turned bright yellow, After twenty-four hours in darkness on the water bath, the films were nearly colourless. Comparative tests showed that although the bleaching of chlorophyll by oxidation at 100°C. is rapid, it is not as rapid as in sunlight at 30-35°C.

Films prepared from a petrol ether solution separated from an alcoholic solution, to which copper sulphate had been added, remained green after an hour on the boiling water bath, and still showed colour after twenty-four hours. The copper compound with chlorophyll is therefore more resistant than chlorophyll, not only to photo-oxidation, but also to thermo-oxidation.

Chlorophyll films in large sealed tubes filled with carbon dioxide kept at 100°C., within one to two hours became bright yellow. The petrol ether extract was dark yellowish in colour, showed a strong fluorescence, and gave the spectrum of phaeophytin. It yielded no appreciable ash. Apparently at high temperatures carbon dioxide acts readily on chlorophyll, removing its magnesium and producing phaeophytin.

The photo-oxidation of xanthophyll.

In a previous paper it was suggested that portion of the oxygen produced during the interaction of carbon dioxide with chlorophyll might be used to oxidise xanthophyll into phytol, hexose sugars and formaldehyde. This suggestion was based upon data obtained by passing moist oxygen over dry "xanthophyll" films in tubes exposed to light. Further experiments carried out with films exposed to light under water kept saturated with air gave no trace of formaldehyde on distilling the oxidised liquid. The method of obtaining the xanthophyll used in these experiments yields a product which though free from chlorophyll, contains a high proportion of xanthophylloid and other impurities.

Owing to their presence, the impure "xanthophyll" obtained as previously described is temporarily soluble in petrol ether. Films from petrol ether solutions were covered with water exposed to sunlight and frequently shaken with fresh air, until the film breaks up to form a white, milky liquid. In addition strong alcoholic solutions were poured into water and similarly exposed. The products in this case are the same, but the bleaching is more rapid.

The watery liquid was then evaporated to dryness and the brown, gummy residue digested with a small quantity of cold water and filtered. The clear brown filtrate has a slightly sweetish taste, followed by the bitter flavour of wax impurities. If the digestion is prolonged in a larger quantity of water, the whole residue breaks up, and the less soluble portion swells to form a colloidal solid which is difficult to separate by filtering. It can, however, be condensed by the addition of a few drops of lead acetate.

The filtrate and also the filtrate from the photo-oxidation in water of impure chlorophyll from the first petrol ether separation gave the following tests :—

1. With *a* naphthol and sulphuric acid it gave the furfural test for carbohydrates (green ring, red above, purple on cooling and shaking).
2. Warmed with phloroglucin and hydrochloric acid, the solution deepened slightly in colour, but gave no pink. Hence no pentoses were present.
3. Strong reduction with Fehling's test not increased by previous warming with a drop of sulphuric acid. Hence no cane sugar present, but maltose, glucose or levulose.
4. With hydrochloric acid and resorcin it gave one warming a red liquid and a brown precipitate on standing. Since cane sugar is not present this shows the presence of a keto hexose such as levulose.
5. Milk of lime was added, and the liquid filtered.

Precipitate.—A portion dissolved in HCl. gave a fairly strong reduction with Fehling's test. A second portion was neutralised, and phenylhydrazin hydrochloride and sodium acetate added. After warming half an hour on a water bath a finely granular yellow glucosazone precipitate was given = presence of levulose.

Filtrate gave a blood red with picric acid and sodium hydrate.

Carbon dioxide was passed into the remainder of the filtrate, which was then evaporated to dryness, water added and refiltered. The filtrate gave a fairly strong reduction with Fehling's test, but not as strong as before the precipitation of the levulose. Presence of glucose.

In a further experiment, the watery extract from oxidised "xanthophyll," after clearing and filtering, was treated with ammonical lead acetate and filtered. The precipitate was washed, suspended in water, carbon dioxide passed through, and again filtered, The filtrate was evaporated to dryness, dissolved in a minimum of water, and cleared and decolorized with animal charcoal. The

solution had a sweetish taste, was dextro-rotary, and gave a strong reduction with Fehling's test.

The precipitate from the carbon dioxide was suspended in water, sulphuretted hydrogen passed through and filtered. The filtrate was evaporated to dryness, and the nearly colourless gummy residue dissolved in water and filtered. It was sweetish in taste, laevorotary, and gave a strong reduction with Fehling's test.

Hence the sugars produced are a mixture of dextrose and levulose, and probably in equal proportions since the original solution showed a slight laevorotation.

In a further experiment Pasteur's solution was added to a watery extract from photo-oxidised "xanthophyll," and a drop of water containing 10 to 20 yeast cells. The tubes were sealed, and kept at 25°C. In one week, yeast cells were abundant, and actively budding, carbon dioxide was formed, and the filtered liquid gave the iodoform test for alcohol. The sugars are, therefore, fermentable by yeast.

In the above experiments the "xanthophyll" used contained not only "xanthophylloids," but also other extractives. Accordingly pure preparations of xanthophyll were prepared by slight modifications of the methods used by Willstatter and Mieg. (Lieb. Ann. 355 .1. 1917). Chopped dry grass leaves (4 kilogrammes) were extracted with alcoholic potash. The filtered liquid was treated with excess of ether and a separation effected by the addition of water. The red ether extract was washed with water, dried with anhydrous sodium sulphate, concentrated, and petrol ether added. The red precipitate which forms, was dissolved in hot acetone and filtered after cooling and standing, leaving a white solid, and a dark almost black liquid (orange red when dilute). To this, twice its volume of methyl alcohol was added, and on standing in darkness and out of contact with air, pure xanthophyll crystallizes out, and can be finally washed with petrol ether.

The xanthophyll obtained was exposed to photo-oxidation as dry films in tubes in a current of air, and in the form of a fine emulsion in water. No trace of reducing or non-reducing sugar could be detected after oxidation whatever the method used. In the first experiments traces of formaldehyde seemed to appear, particularly when the photo-oxidation was rapid. It was found, however, that the methyl alcohol used for precipitating the xanthophyll yielded traces of formaldehyde when exposed to sunlight. On removing this source of error no formaldehyde could be detected as a product of the oxidation of xanthophyll. It is worthy of note that pure

samples of xanthophyll oxidize and bleach much more slowly in light than do impure samples, xanthophyll being less readily oxidizable than chlorophyll, and very much less so than carotin. The white waxy solid separated by acetone during purification was exposed to light. No production of sugar or formaldehyde could be detected.

Dry films obtained from the first ether separation yielded small amounts of reducing sugar after photo-oxidation, and this even when the films had been previously well washed with water. The inference might be made that xanthophyll oxidized in the presence of certain associated substances yields sugar, but not when oxidized by itself. The addition of a few particles of magnesium powder retards the oxidation of pure xanthophyll greatly, but no sugar or formaldehyde appears.

To an alcoholic solution of impure "xanthophyll" which yielded sugar readily on photo-oxidation, alcoholic potash was added. A reddish yellow precipitate formed, insoluble in petrol ether, acetone or ether, but dissolving readily in water, and consisting almost wholly of reducing sugar. On now separating the xanthophyll solution with ether, no trace of sugar could be obtained from dry xanthophyll films after photo-oxidation. The impure xanthophyll films evidently contain preformed sugar, possibly held in loose combination, so that it is not readily removed by washing with water, but is easily separated from an alcoholic solution by the addition of potash.

In the purification of the ether solution of xanthophyll by precipitation with ether, a large amount of yellow xanthophylloid material remains in solution, and is not precipitated from an acetone solution by methyl alcohol. This forms a yellow oily solid with a low melting point. It is readily soluble in petrol ether. Boiled with water it yields neither formaldehyde nor reducing sugar. Films exposed to sunlight bleach fairly rapidly. They usually yield a trace of acetone (Schiff test, etc.) when previously washed and dried, but give no formaldehyde, Schryvers, Rimmers, and the Schiff, and sulphuric acid tests being all negative. The watery extract from the bleached films when evaporated to dryness dissolved in a little water and filtered, gave in all cases the test for a reducing hexose sugar.

In a further test, with pure xanthophyll, nearly half a gram was spread as a film inside a large flask exposed to strong sunlight, with a slow current of moist CO_2-free air passing through the flask and then into water in a darkened receiver. The film was wholly

bleached in three days. The water in the receiver gave Schiff's test strongly, Schryvers, Rimmers, and the Schiff and sulphuric acid tests faintly. It apparently contained a trace of formaldehyde in addition to a trace of acetone, but not sufficient of the former to give the characteristic smell.

Apparently when subject to violent photo-chemical oxidation pure xanthophyll may produce traces of formaldehyde, but none when the oxidation takes place in darkness or in weak illumination or under water. According to Willstätter, Mayer, and Hüni (Annalen, 1910, p. 73), the constitutional formula of phytol may be

$$\begin{array}{ccccccccccccccccccccc} CH_3 & - & CH & - & CH & - & CH & - & CH & - & CH & - & CH & - & C & = & C & - & CH & - & CH_2O \\ & & | & & | & & | & & | & & | & & | & & | & & | & & | & & \\ & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & \end{array}$$

Phytol would therefore be constructed from similar building materials to aliphatic and cyclic terpenes and rubber. Just as geraniol and limonol may be constructed from two molecules of isoprene, so may four molecules form phytol, as thus :—

$$4C_5H_8 + H_2O + 3H_2 = C_{20}H_{40}O$$

In the same way eight molecules of isoprene might yield carotin ($C_{40}H_{56}$) or xanthophyll ($C_{40}H_{56}O_2$).

$$8C_5H_8 + 2.O_2 = C_{40}H_{56} + 4H_2O$$
$$8C_5H_8 + 3.O_2 = C_{40}H_{56}O_2 + 4H_2O$$

It would not be surprising that under violent photo-oxidation some of the $CH-CH_3$ components of carotin, as well as of phytol, and hence also of chlorophyll, might be torn away, and oxidized to formaldehyde, and as thus $(CH-CH_3)+O_2=2\ CH_2O$. If so, the presence of two additional atoms of oxygen in the xanthophyll molecule renders it not only more stable in this respect, but also more resistant to oxidation than is carotin.

According to Willstätter and Stoll, pulverised xanthophyll takes up 36.5% by weight of oxygen and produces a compound which when precipitated from methyl alcohol by ether has the formula $C_{40}H_{56}O_{18}$ This is, however, merely a percentage formula, and gives no indication of the mode of union of the oxygen.

The oxidation of carotin.

In the experiments described in the previous paper, films of carotin were exposed to light in a current of moist air. Using watery emulsions of carotin exposed to light and air, the oxidation was much more rapid than in the case of xanthophyll, the liquid

when distilled yielded appreciable quantities of formaldehyde, but no trace of reducing sugar was formed.

The quantitative weighings of dry films during oxidation indicated that further oxidization is possible after the carotin has been bleached white.

The presence of an oxidase strongly accelerates the oxidation of carotin both in light and in darkness. A solution of carotin in hot alcohol was poured into water so as to form a yellow turbid emulsion. This was divided into four parts, A, B, C, D. To A and C a few drops of a solution of copper sulphate and salt were added, which acts as a strong oxidase. A and B were exposed to sunlight, C and D were kept in darkness in beakers with a large free surface exposed to air. In A and C the emulsion, owing to some mechanical action of the copper sulphate, aggregates to larger particles, which would tend to delay oxidation, but nevertheless A was fully bleached in two days, B in four days, C in six days, and D even after eight days was still reddish yellow, but somewhat paler. A yielded a distinct trace, B a doubtful trace, and C and D no trace of formaldehyde on distilling.

A curious result was given by a carotin solution obtained by boiling the expressed juice of grated carrots, washing the floating red mass with absolute alcohol, dissolving in hot absolute alcohol and separating with petrol ether. Emulsions were made by evaporating to dryness, dissolving in absolute alcohol, and adding water. Repeating as above, the oxidized liquids were filtered, evaporated to dryness, and the residue digested with cold water for twenty-four hours, filtered, and then tested for reducing hexose sugars. A gave strong positive results, B weak positive results, C fairly strong positive tests, and D doubtful or negative tests.

The appearance was given as though the addition of a metallic oxidase caused carotin to oxidize to carbohydrates. The solutions used, however, contained carotinoids as well as carotin, and carotin purified by precipitation did not yield any sugar on oxidation under any conditions.

From the original alcoholic carotinoid solution sugar separated, when it was treated with alcoholic potash. The liquid A and C after oxidation filtered clear, whereas B and D filtered turbid, and left waxy residues, which apparently held sugar as a physical mixture or in loose chemical union, and from which even long contact with cold water removed the sugar only to a slight extent or not at all. Hence the apparent production of sugar on photo-oxidation in the presence of copper sulphate and salt.

The conversion of xanthophyll into carotin.

Haas[1] and Hill state apparently on the authority of Palladin[2] that carotin is converted by a plant oxidase into xanthophyll, and xanthophyll by a reductase into carotin. The same statement is definitely referred to Palladin by C. J. West,[3] but is evidently transcribed from Haas and Hill. As a matter of fact Palladin does not mention either carotin or xanthophyll in the papers quoted. He shows that reductases are present in plants as well as oxidases. The respiratory oxidases, he considers to be pigment forming oxidases, and (on p. 385) "at present we only know that the respiratory chromogens are aromatic compounds; while in the living plant the respiratory pigments usually occur as colourless chromogens, and when present in coloured form (beet root, etc.) can be reduced to colourless compounds."[4]

In my previous paper[5] I was also misled into ascribing this statement to Palladin, but could obtain no evidence of any action of either watery or glycerine extracts of plants oxidases and reductases on carotin or xanthophyll. This may possibly be because of the difficulty of reproducing the conditions existing in the plant. Experiments were, however, made with the pigments in various solvents, and in the form of fine emulsions in water.

The results obtained with metallic reductases were more satisfactory. As already shown, magnesium dust rapidly, and zinc dust slowly, reduce xanthophyll, present in a clear yellow solution in a mixture of alcohol and water, to carotin, leaving the liquid nearly colourless. Using strong emulsions of xanthophyll in the form of suspended particles, zinc dust was found to be ineffective and magnesium dust only acted slowly. In the latter case on filtering, drying and dissolving, the dry residue in petrol ether, the bulk of the pigment consisted on evaporating of yellow xanthophylloids with scattered minute red particles of carotin. The tests should be done in darkness, and as far as possible out of contact with the air since otherwise the carotin may oxidize to colourless products.

All attempts to convert carotin into xanthophyll by the aid of metallic oxidases, organic oxidases (carrot, potato, apple) or direct

1 Chemistry of Plant Products, p. 252.

2 Ber. d. D. Bot. Ges. 1908, 26, A, pp. 125, 378, 398; (1909), 27, p. 110. Zeitschr. f. Physiol. Chemie. (1908), 55, p. 207.

3 Biochemical Bulletin, 1915, p. 184.

4 Zeits. f. Physiol. Chem., Bd. 55, 1908, p. 221.

5 Proc. Roy. Soc., B, 89, 1915, p. 11.

oxidizing agents failed, whether solutions or emulsions in water were used. Lubimenko[3] finds, however, that both carotinoids and xanthophylloids exist which are intermediate between xanthophyll and carotin. The carotinoid from the aril of Euonymus is indeed insoluble in petrol ether, while xanthophylloids are soluble to a greater or lesser extent. According to Lubimenko, in the absence of oxygen, the xanthophyll decreases and the carotin increases, while in boiled leaves exposed to air and peroxidase, the carotin is converted into a yellow pigment equally soluble in alcohol and petrol ether, and with a spectrum intermediate between carotin and xanthophyll.

The influence of the absence and presence of carbon dioxide.

Mustard seedlings were grown in moist air in diffuse daylight, and under similar conditions in air deprived of carbon dioxide. The cotyledons in the first case were larger, broader and more yellowish green, and in the second were smaller, darker and more bluish green. The cotyledons with the upper half of the hypocotyl were removed, and the crushed material after killing by boiling was extracted with successive portions of absolute alcohol, and finally with hot alcohol. The last extraction was nearly pure carotin, and showed clearly that the seedlings grown in the absence of carbon dioxide contained more carotin than the others.

The whole extract was divided into three parts. From one the chlorophyll was separated by three successive petrol ether extractions, and the amount of chlorophyll estimated by comparison with solutions of known strength. The second sample was evaporated to dryness, dissolved in a minimum of cold absolute alcohol, saponified and separated with ether. The third sample was saponified, petrol ether added, and then water. After washing the petrol ether and ether solutions, their strengths were estimated by comparison with solutions of known concentration. This method is not wholly accurate, but in the complete separation of chlorophyll, carotin and xanthophyll, the losses are so great that the exact estimation of the amounts originally present is impossible.

The values obtained were :—

	Weight of Material. grammes.	Chlorophyll. grammes.	Carotin. grammes.	Xanthophyll. grammes.
CO_2 present	100	0.474	0.11	0.15
CO_2 absent	100	0.271	0.275	0.12

1 Compt. Rend. 1915, p. 278.

The dark blue green colour, therefore, appears to be due not to an excess of chlorophyll, but rather to the more compact character of the tissue, and it appears as though chlorophyll develops most rapidly when its normal functional activity can be exercised. The conclusion seems also justified that the carotin supplied at least a part of the carbon and hydrogen for the construction of chlorophyll.

The spontaneous decomposition of chlorophyll.

Twenty pounds of grass leaves were extracted with absolute alcohol, and separated with two litres of petrol ether. After washing with 80% alcohol, the petrol ether solution containing a little alcohol and a trace of water was placed in a completely filled bottle. The percentage of chlorophyll was estimated by diluting against a sample of pure chlorophyll and comparing under the spectroscope. The bottle was sealed and kept in darkness for one year. On opening and diluting a sample the colour was strongly yellowish green instead of pure green. The solution was divided into four parts.

One part was evaporated to dryness, and treated with cold absolute alcohol. This left behind a large amount of a brownish white waxy film, readily soluble in petrol ether. The solution was diluted down to a dilute solution of known strength, in which only the red band of chlorophyll was visible. This indicated that per gram of the original chlorophyll only 0.54 gram remained.

To the second portion of the petrol ether solution twice its volume of absolute alcohol was added, and sufficient hot water to bring about separation. After standing three days in darkness the subnatant liquid was deep yellow, and a layer of solid red particles was present between the two liquids. These were collected and washed. They consisted mainly of xanthophyll, with a little carotin.

The third portion was evaporated to dryness in the form of a film lining a large tube. It weighed 4.452 gram. After soaking in cold absolute alcohol for several days, the brown waxy film remaining was washed and dissolved in petrol ether. On evaporating, it weighed 1.309 gram, and on incinerating after warming with a drop or two of nitric acid it yielded 6.8 per cent. of ash as magnesium oxide. According to Willstätter, the phyllins (glaucophyllin and rhodophyllin have the formula ($C_{31}H_{30}N_4Mg(COOH_2)$) which represents 7.1% of ash as magnesium oxide.

The fourth portion was agitated with a little water, the petrol ether allowed to evaporate and the residue distilled. The distillate contained distinct traces of formaldehyde.

Hence impure chlorophyll appears to spontaneously undergo partial segregation into carotin and xanthophyll, and pale brown waxy solids rich in magnesium. In addition small quantities of formaldehyde appear. An equation for the production of glaucophyllin and carotin from chlorophyll cannot be made to balance without the addition of oxygen, but small quantities of dissolved or occluded oxygen might have been present before sealing, as this possibility was overlooked. In that case a suggested equation might be—

$$2C_{31}H_{29}N_4Mg\begin{cases}\left.\begin{matrix}COOH\\COOCH\end{matrix}\right\} + 4.O_2 = 2C_{31}H_{30}N_4Mg(COOH_2) + C_{40}H_{56}\\ \qquad\qquad\qquad + 4CH_2O + 8H_2O\\ COOC_{20}H_{39}\end{cases}$$

If a similar change resulted in the production of the monocarboxylic phyllophyllin ($C_{31}H_{31}N_4Mg.COOOH$) still less oxygen would be required.

In samples of chlorophyll purified by precipitation, no carotin or xanthophyll appeared, and dry samples kept in sealed vacuum tubes were apparently unaltered after five months in darkness. In the case of dry samples from the unpurified petrol ether extract, after keeping for some months, the sample will flow slowly over the glass, and shows a separation of solid red carotin or xanthophyll particles.

The Precursors of Chlorophyll.

According to Timiriazeff[1] and to Monteverde[2] etiolated leaves yield a small amount of fluorescent pigment which they term "protochlorophyll," This, according to Monteverde and Lubimenko,[3] is a derivative of the labile "chlorophyllogen," which rapidly turns into chlorophyll when exposed to light. The precursor of this theoretical substance is. according to the same authors, a colourless theoretical substance, "leucophyll."

Kohl[4] showed that etiolated seedlings contained carotin in abundance, and even doubted whether any other pigment was present. He also found that the percentage of carotin did not decrease during the formation of chlorophyll on exposure to light, and hence denied that any conversion of carotin into chlorophyll components took place. Kohl's observation might, however, merely indicate that while food materials were abundant, the production

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1 Compt. rend., 102, 686 (1886); 414 (1889).
2 Acta. Horti. Petropol., 13, 201 (1894); Bull. Lard. Imp. Bot. Petrograd, 7, 37 (1907).
3 Biol. Central, 31, 449 (1911); Bull. Ac. Imp. Sci. Petrograd, 73 (1911); 609 (1912).
4 Untersuchungen uber Carotin, 75 (1902).

of carotin continued at a greater rate than it was used in the formation of chlorophyll.

To test this, two batches of wheat seedlings were grown in darkness, until approaching partial starvation. One batch was then exposed to full sunlight for one day. Equal quantities were then dipped in boiling water, the surplus water squeezed out, and the leaves twice digested with cold absolute alcohol on two successive days. The fully etiolated leaves were still deep yellow, and with hot alcohol gave a strong, nearly pure solution of carotin. Those which had been exposed to light were nearly colourless, and gave a pale yellow solution with hot alcohol, containing only a small amount of carotin.

Kohl is, however, correct in stating that carotin is the chief pigment in etiolated seedlings. Complete extractions with etiolated wheat seedlings yielded from 8 to 10 parts of carotin to one of xanthophyll, the percentage may of course vary with other seedlings, and after prolonged etiolation it appears to decrease.

If colourless precursors of chlorophyll exist, they should have a high magnesium content, and should be capable of separate extraction. An area of ten square feet of closely planted wheat was kept in darkness until the seedlings were six inches high. The yellow leaves were cut at once and dropped into boiling water, and after squeezing out all excess of water, twice digested in cold alcohol for periods of a day, all liquid being squeezed out in a strong press after each extraction. The nearly colourless material was then digested in boiling absolute alcohol for five hours. The solution was filtered hot, petrol ether added while still warm, and sufficient water to bring about separation. After standing for a day the pale yellow petrol ether extract was evaporated to dryness, and the residue dissolved in a minimum of hot alcohol. In this solution, after standing for one day, a bulky white crystalline solid separates out which appears to contain alcohol of crystallization. After filtering and washing with a little absolute alcohol a pale brownish white solid was obtained. This gave off alcohol when heated, and after incinerating with a drop of nitric acid yeilded 1.5% of ash as magnesium oxide.

The original precipitate, however, appears to consist of two solids —(a) a white wax less soluble in cold alcohol than carotin, but readily soluble in hot alcohol; and (b) a browner wax, which is still less soluble in alcohol, than the preceding, and can be separated from it by washing with small amounts of warm alcohol. This less soluble browner wax yielded in one experiment 6.2% of ash as mag-

nesium oxide, and in another 7.4%. The discrepancy is considerable, but the difficulty of purifying without great loss of material is very great. The amounts of solid obtained for incineration were only 0.35 and 0.42 gram. respectively. Presumably, the original precipitate consists of a darker waxy solid, with a high magnesium content, and a paler wax with little or no magnesium, which may possibly partly be derived from the wax impregnating the cuticle. and have nothing to do with chlorophyll.

The wax present in the cuticle does not, however, decrease with starvation, and increases in amount with increasing age. In a further experiment the seedlings were grown in darkness until nearly starved, and the yellow leaves were treated as before. The waxy solids obtained after separation from petrol ether and crystallization from hot alcohol gave a yield of 5.1% magnesium oxide. The amount obtained was insufficient for the separation into magnesium containing and non-magnesium containing waxes, but the result indicates that the waxy solids with little or no magnesium decrease during starvation, and hence are not derived wholly from the cuticle.

The decomposition of chlorophyll in grass leaves in darkness.

Plots of barley grass (Hordeum murinum) were kept in darkness from just before the commencement of flowering until the greater part of the leaves turned yellow or yellowish red. These parts were cut away and extracted. A little chlorophyll was still present, as well as xanthophyll and carotin, in the approximate proportions of 1, 3 and 12 respectively. The pale brownish white wax obtained as previously described yielded 1.15% of ash. After washing with warm alcohol the darker residue remaining yielded as much as 12.9% of ash, but the whole of this did not consist of magnesium oxide.

Many of the old grass leaves were bright red in colour, and remain so in darkness, until they died and shrivelled. These were extracted with absolute alcohol and petrol ether until all carotin and xanthophyll were removed. They were still red. They imparted a red tinge to water and the red pigment rapidly dissolved in dilute hydrochloric acid or dilute potash. The neutral solution in water was precipitated by lead acetate, turned yellow with sodium hydrate, reddish brown with hydrochloric acid, and dark reddish brown, with ferric chloride. It was apparently, therefore, a flavone, and as it appeared to develop in or in the neighbourhood of the chloroplastids, it may be one of the products

of the progressive decomposition of chlorophyll in darkness. In any case the formation of a pigment of this character is darkened leaves in unusual. Extractions of additional material, with alcoholic potash containing a little water yielded potassium rhodophyllin, but whether this was partly responsible for the red colour or was merely derived from the chlorophyll, is impossible to say.

In the case of most green leaves, the chlorophyll decomposes more or less rapidly in darkness. This is possibly primarily due to the action of the carbon dioxide produced by respiration, aided by subsequent oxidation, and by the absence of the chlorophyll regeneration normally carried on in the presence of light. It is worthy of note that in fleshy plants such as cacti, where in darkness a formation of organic acids may largely replace the normal carbon dioxide production, the leaves remain green unusually long in darkness. The same applies to water plants such as *Elodea* and *Chara*, in which the carbon dioxide is removed in solution by the water outside.

The photo-oxidation of rhodophyllin.

An alcoholic solution of chlorophyll containing a little water was heated on a water bath with potash for twelve hours. Excess of water was added, and the liquid was placed in a stoppered Winchester, shaken and allowed to settle daily for three days. The supernatant liquid was syphoned off, and the residue filtered. The residue was well washed with water, dried washed with a little absolute alcohol, and then treated with hot alcohol containing a little water. The red filtrate on standing formed red crystalline platelets, with a bluish metallic lustre. From this potassium rhodophyllin, rhodophyllin was obtained by treating with acid sodium phosphate and subsequent separation.[1] The product was readily soluble in ether and alcohol.

Films and watery emulsions of rhodophyllin and of its potassium salt were exposed to light. The latter was slightly more resistant to photo-oxidation than the former, but both proved to be much more stable and resistant to photo.-oxidation than either chlorophyll or xanthophyll. No formaldehyde or reducing sugar could be detected as a product of the photo-oxidation, either in the absence or in the presence of carbon dioxide.

Since rhodophyllin is comparatively stable, and resistant to photo-oxidation, it would be natural to find that it would be one of the products of the decomposition of chlorophyll in autumnal

1 Willstatter and Pfannestül, Annalen, 358, 1908, p. 205.

leaves exposed to light. Brown leaves of Salix Babylonica were collected in quantity and boiled and pressed repeatedly until all the soluble tannins were removed. They were then washed with absolute alcohol, and extracted with hot absolute alcohol.

The liquid was filtered, concentrated and cooled and refiltered. The brown waxy solid removed consisted partly of phaeophytin. Ether was added to the alcohol and then salt. The reddish yellow ethereal layer contained all the pigment. After washing with water and drying with sodium sulphate, it was evaporated. The residue was extracted with methyl alcohol, leaving a white waxy solid undissolved. To the liquid, alcoholic potash was added, and after heating, it was filtered. On standing, shining red platelets with a steely blue shimmer of potassium rhodophyllin separated out.

Yellow leaves picked off the tree and kept in darkness for three days turned brown, as in fallen leaves, so that the change is not necessarily due to light. They yielded, however, xanthophyll largely on extraction and rhodophyllin only in small amount.

Rhodophyllin was also obtained from the brown autumnal foliage of the English oak. When these are red in colour erythrophyll is present in the cell sap, but it soon fades, leaving them a pure brown colour. The colour of such leaves is due to several pigments of which the erythrophyll fades first, then the xanthophyll, then the rhodophyllin and the permanent brown colour is due practically wholly to oxidized tannin compounds.

The evolution of oxygen from etiolated plants.

It appears from the foregoing that etiolated leaves contain carotin, a little xanthophyll, and a nearly colourless waxy solid rich in magnesium, which is either glaucophyllin, or is related to it. Carotin appears to be the first pigment formed in the construction of chlorophyll, and presumably it is produced at the expense of carbo-hydrate or of hydrocarbon food materials. The relative amounts of carotin and xanthophyll in etiolated parts may depend upon the relative activities of oxidase and reductase enzymes respectively.

When an etiolated plant turns green in light, it seems reasonable to suggest that the carotin undergoes photo-oxidation,[1] liberating formaldehyde, which is rapidly polymerized, and that the bleached

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1 In the case of plants able to develop chlorophyll in darkness, an oxidase enzyme could produce the same effect.

carotin residue combines with the glaucophyllin, converting it into the tricarboxylic chlorophyll. This process involves an absorption of oxygen. If carbon dioxide is present, it interacts with the chlorophyll, probably undergoing additive combination. If it then separated formaldehyde and phytyl, it would liberate a large amount of oxygen. The phytyl would then recombine with the glaucophyllin, reforming the chorophyll molecule. If the supply of carbon dioxide was abundant in proportion to the intensity of illumination, the decomposition and recombination would balance and an evolution of oxygen would be possible without any actual accumulation of chlorophyll taking place. In 1896 I was able to confirm on a variety of plants the statements of Draper and of Englemann that etiolated chloroplastids can evolve oxygen in light,[1] and showed that this took place before any actual chlorophyll was developed. The rule was not a universal one, however, and particularly in the case of maize, which has a high temperature minimum for the formation of chlorophyll, no evolution of oxygen could be detected from etiolated leaves so long as they were free from chlorophyll. It was also shown that sealed preparation of etiolated leaves of Elodea with Bacteria, owing to the presence of an excess of carbon dioxide did not turn green in light, although they produced the small amount of oxygen necessary to support protoplasmic streaming.

The presence of from 2% to 5% of carbon dioxide in the surrounding air distinctly retards the turning green of etiolated grass seedlings as compared with those in ordinary air,[2] but if the intensity of the illumination is approximately quadrupled, the retarding action of the carbon dioxide is less pronounced or even ceases to be perceptible. Kohl[3] ten years later without referring to the previous work reconfirmed the statement that etiolated plants may evolve oxygen in light. He showed that carotin was the chief pigment in etiolated plants, and held that it was responsible for the assimilation of carbon dioxide in the absence of chlorophyll. It is, however, more probable that the evolution of oxygen takes place as outlined above, and that carotin is not by itself capable of causing the assimilation of carbon dioxide. Actual observation shows that it does not appear to combine with carbon dioxide, and that it combines more energetically and rapidly with oxygen than either chlorophyll or xanthophyll does. The formaldehyde produced

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1 See Journal of Linnean Society, vol. xxxi., 1896, p. 554.
2 See also Bohm, Sitzungsb. d. Wien. Akad., 1873, p. 14.
3 F. G. Kohl, Ber. d. D. Bot. Ges., 1906, vol. xxiv., p. 222.

during its photo-oxidation does not appear to be directly derived from carbon dioxide.

Kohl states that etiolated plants exposed to light in the absence of oxygen, but in the presence of a little carbon dioxide, slowly turn green, the oxygen set free by the agency of the carotin being used in the formation of chlorophyll. It is doubtful, however, whether a complete absence of oxygen was assured at the outset, for Correns[1] has shown that the production of chlorophyll is closely dependent upon the presence of oxygen, and that a partial pressure of oxygen, at which growth and heliotropic curvature are still possible, does not suffice for the formation chlorophyll.

The evolution of oxygen from green plants in light.

It is a difficult problem to determine how the oxygen produced in close contact with pigments capable of rapid photo-oxidation is able to escape from the cell. No production of oxygen could be obtained from extracted chlorophyll, carotin or xanthophyll in the presence of oxidase or reductase enzymes in light or darkness and in the presence or absence of carbon dioxide. It seems legitimate, however, to assume that the large chlorophyll molecules may have a definite physical arrangement in the protoplasm of the chloroplastids. If their phytyl radicles were all turned outwards towards the entering carbon dioxide, and carotin or xanthophyll were produced by additive combination with the latter, the surplus oxygen could either escape or disintegrate the carotin or xanthophyll, back to phytyl. For the latter a portion only of the oxygen is required. The oxidation films formed from carotin, chlorophyll and xanthophyll are very impermeable to oxygen, so that the excess would diffuse outwards. So long as the supply of carbon dioxide was sufficient to replace the xanthophyll or carotin film, as it was oxidized, and as the phytyl returned to the chlorophyll molecule, the chlorophyll would remain unoxidized, but if the intensity of illumination increased greatly, oxygen would slowly penetrate the chloroplastid, bleaching it.

Phytol itself forms a series of compounds with varying proportions of oxygen ($C_{20}H_{38}O_2.C_{20}H_{34}O_9$), etc.,[2] and it also forms an ozonide $C_{20}H_{40}O_5$, which spontaneously separates into $C_{20}H_4O.O_3$ and free oxygen.[3]

The possibility of a reductase enzyme, converting zanthophyll into carotin, with a liberation of free oxygen also needs considera-

1 Correns, Flora, 1893, p. 14.

2 Willstatter and Hocheder, Annalen der Chemie, 1907, 353, p. 205.

3 Willstatter, Mayer and Humi, Annalen, 1910, p. 73.

tion. Against this possibility we have the fact that free oxygen oxidizes carotin more rapidly than xanthophyll, and that the only reductases which seem able to effect the reduction of xanthophyll to carotin appear to be such as themselves readily combine with free oxygen.

In the absence of light the presence of a film of carotin or xanthophyll on the surface of the chloroplastid would render the further penetration of carbon dioxide very slow, and would largely protect the chlorophyll, so long as the plastid was living, from decomposition by carbon dioxide during darkness.

The now well recognised fact that chloroplastids may be rendered temporarily inactive without necessarily being killed, and while appearing normal,[1] is sufficient evidence that the continued assimilation of carbon-dioxide involves a definite relationship between the chlorophyll and protoplasm of the chloroplastid. In other words the physical structure of the chloroplastid may be as important as the chemical composition of chlorophyll. Some special arrangement must exist to protect the chlorophyll from the direct chemical action of the carbon dioxide, which would otherwise remove the magnesium from the chlorophyll and convert it into phaeophytin.

The polymerization of formaldehyde.

Butlerow (Liebeg's Annalen, 120, p. 295, 1861) obtained a bitter tasting syrup "methylenitan," by the action of lime water on trioxymethylene, a polymer of formaldehyde. Loew obtained a sweet syrup by the prolonged action of lime water on 4% formaldehyde. Euler has shown that when a 2% solution of formaldehyde is heated for some hours with calcium carbonate, arabinoketose, a pentose sugar, is produced with glycollicaldehyde as an intermediate product. According to Czapek (Biochemie, 1913, Vol. 1, p. 628), glucose is not produced by the action of alkalies on formaldehyde, but only non-fermentable sugars such as i-Fructose[2] and i-arabinoketose. Fischer, however, obtained from Loew's crude formose an "acrose" sugar, which he was able to convert into levulose.

Both Loew's and Euler's methods are slow and tedious to carry out. A rapid method is as follows:—A saturated solution of formaldehyde is mixed with six times its volume of lime water, and

1 Ewart, Journal Linnean Society, 1896, vol. xxxi., p. 364.

2 Ordinary fructose is fermentable by yeast. See Harden and Young, Proc. Roy. Soc. London, B., 1910. 82, p. 645.

while kept heated to boiling point one and a-half volumes of 12% sodium hydrate are added. The latter portions are added slowly, and if necessary a few drops additional. A white precipitate is formed at first, with each addition of sodium hydrate, which re-dissolves slowly, the liquid remaining alkaline. With the addition of the last few drops, the liquid suddenly clears, become pale yellow, ceases to smell of formaldehyde, but develops a slight caramel smell, and is neutral. If an excess of sodium hydrate is added, the liquid turns brown, and a precipitate may form, but it may be neutralized with a drop or two of acid. On cooling and standing, a white crystalline solid separates, which is insoluble in absolute alcohol, and practically so in cold water. On heating it chars, glows and leaves a bulky chalk ash. It is, therefore, an organic calcium compound. The filtrate gives all the tests for a reducing hexose sugar. It also gives red with picric acid, and sodium hydrate, and gives a caramel smell, and darkens when warmed with sulphuric acid. It gives the keto-hexose reaction, with resorcin and HCl. With phenylhydrazin and sodium acetate, it gives a golden yellow imperfectly crystalline osazone. The liquid showed a feeble laevo rotation.

The diluted liquid, after adding yeast and Pasteur's Solution, keeping at 30°C. for three days, and distilling, gave a product containing an appreciable quantity of alcohol, and giving the iodoform test readily. The sugars are, therefore, in part at least fermentable.

The following procedure was adopted to separate the different products:—

The original syrup contains several compounds. After no more of the insoluble calcium compounds would crystallize out, the syrup was filtered, and twice its volume of absolute alcohol added. A colourless viscid liquid separates and falls to the bottom. After washing this with alcohol it becomes a white viscous solid. On adding water it partly dissolves and a white crystalline solid separates, which when heated chars with a slight caramel odour, and leaves an alkaline ash containing CaO and $CaCO_3$. The filtrate, after the addition of water, gives a strong reduction with Fehling's test. On evaporating nearly to dryness, and cooling, a white crystalline solid separates, which is an organic sodium salt, and the syrup contains sugar. It yields a glucosazone, but gives only a faint reaction with resorcin and HCl., and appears to contain more glucose than levulose.

The original filtrate from the first addition of alcohol is a clear, slightly yellow liquid. On adding twice its volume of alcohol, it becomes turbid; after standing one day a bulky mass of long, slender crystalline needles separates. This, after washing with alcohol, gives no reduction with Fehling's, but chars on heating, and gives an ash of sodium carbonate. It is readily soluble in water, and consists of an organic sodium salt.

The yellow filtrate on evaporating to a thick syrup and cooling, crystallises out the remainder of the sodium salt. The filtered syrup contains mainly hexoses, but also some pentose sugar. Thus distilled with HCl. it turn aniline acetate strongly red, while with HCl. and phloroglucin it turns red, and then gives a brown precipitate soluble in amyl alcohol.

The purified syrup was treated with ammonical lead acetate, and filtered. The filtrate contained pentose sugar. It was evaporated to a small bulk, after treating with CO_2 and filtering, cooled, the liquid drained off, diluted, and Pasteur's ash and yeast added. No alcoholic fermentation took place.

The washed precipitate was treated with carbon dioxide and filtered. The filtrate was evaporated to dryness, dissolved in a little water and filtered. It gave the test for glucose, was dextrorotatory produced a glucosazone, and after adding yeast and Pasteur's ash, the liquid distilled after three days readily gave the iodoform reaction for alcohol.

The remaining solid was treated with sulphuretted hydrogen, and the filtrate evaporated to dryness and dissolved in water. It gave the ketose reaction, was laevoratatory, and produced glucosazone. After adding yeast and Pasteur's ash, the liquid distilled readily, and gave the iodoform reaction for alcohol. Both sugars were also capable of nourishing putrefactive bacteria, *Penicillium* and *Mucor*, when infected with these organisms.

The proportions given above are the most satisfactory for a complete reaction. With less lime water the reaction is less perfect, and less sugar is produced. With more lime water the boiling liquid clears only slowly, between each addition of sodium hydrate, and it is more difficult to obtain a perfectly neutral liquid at the end of the reaction. On cooling, however, a larger amount of the calcium salt crystallizes out directly, as for instance, when the proportions used are 50 c.c. of 40% formaldehyde, 500 c.c. of lime water, and 65 c.c. of 12% sodium hydrate. The crude sugar consisted almost entirely of hexoses, with apparently a trace of pentose, as it gave the furfural test more readily than a pure hexose solu-

tion, and gave a slight coloration and turbidity with phloroglucin and HCl.

A more rapid but less perfect separation than that given above is effected by evaporating the whole synthesized product nearly to dryness in a water bath, and adding a minimum of cold water. The calcium salt remains undissolved. The filtrate is again evaporated nearly to dryness, and treated with 90% alcohol. The residue consists of sodium tartrate; the filtrate contains the sugar.

In previous work on sugar synthesis, alkalies have been used singly instead of jointly, and not as here described. As the bye-products described have been saccharates, formates, etc., with which the calcium and sodium salts did not agree, a precise determination of their character was necessary.

Professor E. W. Skeats investigated the crystallographic character of the calcium salt, and found that it belonged to the orthorhombic system, forming pyramids, domes and elongated pinacoid pyramids, with parallel sides. The crystals were strongly, doubly refractive, optically negative, and had a mean refractive index of 1.55. Mr. J. W. Clendinnen carried out a complete analysis of pure samples of the two salts.

Analysis of two Crystalline Salts obtained by Professor Ewart.

The calcium salt was in the form of well defined crystals, and so needed no further treatment to purify it. As the salt was evidently one of an organic acid, simple ignition left a residue of calcium oxide, from which the percentage of calcium could be calculated.

A combustion was then done with the calcium salt, and this gave the percentages of hydrogen and carbon, and thus oxygen by difference.

These were the results obtained:—

Element.	Percentage. Duplicates.	Mean.	% At wk.	Approx. Ratio % At wk. × .385.
Ca	15.37, 15.45	15.4	.385	1
H	4.91, 4.90	4.9	4.9	12
C	18.84, 18.69	18.7	1.56	4
O		61.0 (diff.)	3.81	10

This formula $(CaH_{12}C_4O_{10})$ corresponds with that of calcium tartrate $CaH_4C_4O_6.4H_2O$. The usual quantitative tests for tar-

trates were then applied to both the salts. All the tests were positive, thus confirming that these were salts of tartaric acid.

The importance of this method of producing sugar lies in the fact that it is a rapid and well defined action, yielding definite salts, namely, sodium and calcium tartrates, and that the amount of sugar produced, particularly of hexose sugars, is large, being intermediate between the weights of the calcium and sodium salts. It is not, however, likely that this mode of producing sugar from formaldehyde is of any importance in the living plant, since it involves a high temperature, and the presence of an abundance of two free alkalies.

Willstätter's and Stoll's[1] *work on Photo-synthesis.*

These authors found that all attempts to produce extracellular photo-synthesis failed, which they conclude is owing to the absence of a hypothetical enzyme from extracted chlorophyll. They found, however, that slight pressure applied to the leaf completely stopped photo-synthesis, which rather supports my own view than an orderly physical arrongement of the chlorophyll molecules in the chloroplastid is an essential factor in continuous photo-synthesis, and that a disturbance or disorganization of this arrangement may be partly responsible for the temporary inactivity into which an apparently normal chloroplastid may be thrown by various agencies or treatments, which when extreme, lead to death and permanent disorganization.

They also conducted experiments on living leaves by passing a mixture of air and carbon dioxide over them in vessels on a water bath exposed to light, and estimating the amounts of carbon dioxide assimilated. They found that the assimilation was not always proportional to the chlorophyll content, a fact already well known to the plant physiologist.

In leaves rich in chlorophyll the authors found that increased illumination did not increase the assimilation, whereas a rise of temperature did, while in leaves deficient in chlorophyll a rise of temperature had little effect, and increased illumination rendered the assimilation of carbon dioxide more active. Hence they conclude that their hypothetical enzyme is in relative excess, and only exercises its maximum effect when the chlorophyll is working at full pressure.

1 Berichte, 1915, 48, 1540.

ADDENDUM, p. 204.

For "sodium tartrate" read "mainly sodium formate with a little sodium tartrate."

The tartrates are only produced under special conditions, details of which are reserved for a subsequent paper, otherwise the bye-products are calcium carbonate, calcium formate and sodium formate.

Willstätter and Stoll have, however, overlooked the principle of limiting factors established by Blackmann and his pupils. In leaves rich in chlorophyll the limiting factor is usually the supply of carbon dioxide and an increase of illumination beyond that necessary to assimilate the carbon dioxide available in a given unit of time is naturally without effect.

An increase of temperature on the other hand accelerates all plant functions, including respiration. In leaves rich in chlorophyll this may not be more than $\frac{1}{20}$ the activity of CO_2 assimilation, but in leaves poor in chlorophyll it represents a large fraction of the CO_2 assimilated. Respiration may be 20 to 40 times as active as 35°C. to 40°C. as at 0°C., and this would be sufficient to prevent any accelerating action of a rise of temperature upon the photo-synthesis of leaves deficient in chlorophyll being shown.

Willstätter and Stoll's results are, therefore, capable of a simple and natural explanation, and do not support the construction they place upon them.

Theories of Photo-synthesis.

From Jörgensen and Kidd's criticism[1] of the results obtained by Usher and Priestly, by Wager and by myself, it would appear as though the work of these authors was completely antagonistic, and mutually contradictory, and therefore of no value. This is not quite a correct view, as the work of each investigator led on to or directly gave rise to that of the next. Thus Usher and Priestley (l.c.) in supposing that they produced photo-synthesis outside the cell, drew attention to facts which otherwise might have been overlooked, and it was their work which led me to determine that the formaldehyde was a direct product of the photo-oxidation of chlorophyll, and was formed in the absence of carbon dioxide. It was a further investigation of their results which enable me to determine that carbon dioxide decomposes chlorophyll in darkness as well as in light. I was in error in concluding that xanthophyll was one of the products of this decomposition, and this error has been corrected by Willstätter as well as by Jörgensen and Kidd, thus bringing our understanding of the changes possible in photo-synthesis a stage further. The direct action of carbon dioxide is to remove the magnesium from the chlorophyll, forming phaeophytin, and I have shown that if zinc dust is present during this reaction, the zinc steps into the place vacated by the magnesium, forming the stable green zinc chlorophyll.

1 Proc. Roy. Soc., vol. 89, B., p. 342, 1917.

The removal of the magnesium from chlorophyll by carbon dioxide, and the fact that magnesium will bring about the combination of carbon dioxide and water to formaldehyde suggests at first sight a possible explanation of carbon dioxide assimilation. This action, however, takes place as well in darkness as in light. Further, the magnesium is separated from chlorophyll as the carbonate, and not in the form of the metal, and if any such action was necessary in photo-synthesis, when the latter was active, the bulk of the chlorophyll would exist in the form of phaeophytin, and the leaf should lose its green colour, which is not the case. Carbon dioxide decompose the chlorophyll in heaped grass leaves in darkness, but in living leaves exposed to light in air rich with CO_2, the chlorophyll remains green. If no carbon dioxide is present, and the illumination is strong, the chlorophyll slowly bleaches, but this is stopped if the supply of carbon dioxide is proportionately increased.

It is more reasonable, therefore, to suppose that the chlorophyll as a whole takes part in photo-synthesis, acting as a light ferment, or lytase enzyme, which, using light energy to draw carbon dioxide and water into its own organisation, breaks down again, liberating them as carbohydrates, and that so long as the supply of CO_2 corresponds to the intensity of the light, and the products are removed, the decomposition and reconstruction of the chlorophyll remain in equilibrium.

There is no difficulty about the decomposition of chlorophyll, but evidence of its regeneration is difficult to obtain.

In a previous paper[1] an account was given of various attempts made to bring about the regeneration of chlorophyll outside the plant. Although indications were obtained suggesting that this might be possible, these were not conclusive. Further attempts in the same direction have so far completely failed. It was frequently observed that in the separation of chlorophyll, alcoholic solutions of xanthophyll, containing the waxy derivatives by precursors of chlorophyll in finely suspended form, when evaporated formed greenish yellow skins, which contained chlorophyll, and left the remaining liquid with little xanthophyll. This happened even when the watery alcoholic liquid showed no trace of chlorophyll under the spectroscope. Further investigations showed, however, that when alcoholic solutions of pure xanthophyll containing a little water are evaporated slowly, the first part of the xanthophyll to

1 Proc. Roy. Soc. Lond., B., vol. 80, p. 30, 1908.

separate out had a greenish colour owing to its physical condition. When dissolved, it shows no trace of chlorophyll. It was further found that a liquid rich in xanthophyll could contain traces of chlorophyll in finely suspended form without any traces of chlorophyll being visible under the spectroscope. This is partly because owing to the opacity of a liquid containing waxy impurities in finely suspended form, only thin layers can be examined. When such liquids are evaporated, and the green solids which first separate out removed and dissolved, the appearance is given of a production of chlorophyll having taken place. In other observations in which chlorophyll appeared to be regenerated with the agency of zinc dust, the apparent regeneration was due to the formation of the zinc compound of phaeophytin, which closely resembles chlorophyll.

Hitherto the regeneration of chlorophyll from its magnesium containing derivatives, and from xanthophyll or carotin under the action of light, has not been possible outside the living plant. Iwanowski[1] states that solutions of chlorophyll containing carotin or xanthophyll are more stable towards light than chlorophyll alone. This may be partly due to a direct protective action, carotin in particular combining more readily with oxygen than chlorophyll does. According to Iwanowski, however, the protective action is more marked when both carotin and xanthophyll are present. This may possibly be because a certain amount of regeneration of chlorophyll takes place with the aid of light energy from the products of its decomposition and from those of the photo.-oxidation of carotin and xanthophyll.

In the case of those plants which can develop chlorophyll in darkness, its building up requires a supply of energy which is either derived from the oxidation of the stored food materials, or which is absorbed directly as heat from outside. It is worthy of note that in all cases the minimum temperature for the formation of chlorophyll is higher than for the formation of carotin or xanthophyll, and plants which can turn green in darkness will do so at a lower temperature in light than they will in darkness.

Until the heats of combustion of chlorophyll, glaucophyllin, phyllophyllin, phytyl, carotin, and xanthophyll are known, it is impossible to discuss the energy changes which may be involved in carbon dioxide assimilation. A large part at least of the energy represented by the carbohydrates produced is undoubtedly light energy, which was absorbed and used in the reconstruction of chloro-

1 Ber. d. D. Bot. Ges., 1913-14, 31, pp. 600-613.

phyll, and the carbohydrates are probably as much a product of photo-analysis as of photo-synthesis. So long as the supplies of carbon dioxide and light energy are in a certain ratio of equivalency, and the products are continually removed, the chlorophyll is externally stable, though internally labile. In other words, it behaves as an enzyme, and, according to whether we emphasize the source of energy or of material, it might either, to coin a term, be regarded as a lytase enzyme or a carboxidase enzyme.

The following equations are put forward not as representing established facts, but as indicating how chlorophyll could act as a photic or lytase enzyme for the conversion of carbon dioxide and water into carbohydrates. The chief difficulty in regard to them is the very large mass reactions which they represent.

$$\text{(i.)}\quad 2C_{31}H_{29}N_4Mg\begin{cases} COOH \\ COOCH_3 + 36CO_2 + 16H_2O = 2C_{40}H_{56}O_2 + 44O_2 \\ \qquad\qquad\qquad\qquad + 2C_{31}H_{30}N_4Mg(COOH_2) \\ COOC_{20}H_{89} \end{cases}$$

Amorphous chlorophyll + carbon dioxide and water would form xanthophyll (or carotin) oxygen and glaucophyllin.

$$\text{(ii.)}\quad 2C_{40}H_{56} + 24H_2O + 8.O_2$$
$$= 2C_{20}H_{39}OH + 3C_6H_{12}O_6 + 3C_6H_{12}O_6 + 4CH_2O$$

Carotin (or xanthophyll) + water + oxygen

= Phytol + levulose + glucose + formaldehyde.

This reaction would take place in light with the aid of an oxidase enzyme and the excess oxygen from (i.) escapes.

$$\text{(iii.)}\quad 2C_{20}H_{39}OH + 2C_{31}H_{30}N_4Mg(COOH_2) + 4CO_2$$
$$= 2C_{31}H_{29}N_4Mg\begin{cases} COOH \\ COOCH_3 + 3.O_2 \\ COOC_{20}H_{89} \end{cases}$$

Phytol, glaucophyllin, and carbon dioxide form amorphous chlorophyll and oxygen.

This change would take place in the living plant with the aid of light energy. It makes the total volume of oxygen exhaled equal to the volume of carbon dioxide absorbed.

This suggested cycle would indicate the enzymatic action of chlorophyll in the presence of water, carbon dioxide and light, and might serve as a basis for further investigation. Written in one line the equations would read :—

$$40CO_2 + 40H_2O + \text{chlorophyll} + \text{light energy}$$
$$= 3\overleftarrow{C_6H_{12}O_6} + 3\overrightarrow{C_6H_{12}O_6} + 4CH_2O + 40.O_2 + \text{chlorophyll}.$$

With an excess of carbon dioxide and a deficiency of light, stage 1 would preponderate. With stronger illumination stages 2 and 3 would balance 1. With excessive illumination and a deficiency of carbon dioxide disintegratory photo-oxidation would take place, and the amount of chlorophyll would be reduced.

Summary.

In the assimilation of carbon dioxide chlorophyll acts as a light energizing enzyme, and takes direct part in the cycle of chemical changes, which probably have carotin, xanthophyll, phytyl and glaucophyllins as intermediate products and glucose, levulose, formaldehyde and oxygen as end products. The sugar may be formed directly as well as through the polymerization of formaldehyde.

A large part of the energy represented by the carbohydrate products is absorbed during the reconstruction of the chlorophyll molecule.

Carbon dioxide decomposes extracted chlorophyll both in light and
The earlier supposition that zanthophyll was one of the products has not been sustained. In the presence of zinc dust, the zinc takes the place of the magnesium, and the chlorophyll remains green as a
in darkness, removing its magnesium, and producing phaeophytin.
stable zinc chlorophyll.

Apart from its protective function, carotin seems to be especially important as providing during its photo-oxidation or partial disintegration, the massive hydrocarbon combination in the phytyl radicle of chlorophyll whose addition is necessary to convert the dicarboxylic glaucophyllin into the tricarboxylic chlorophyll. Xanthophyll can be reduced to carotin by the aid of metallic reductases, but no oxidases have been found capable of converting carotin into xanthophyll. The oxidation of these substances in darkness or in feeble light differs in certain respects from that taking place in intense light.

The oxidation of rhodophyllin, chlorophyll, xanthophyll, and carotin is more rapid at high temperatures than at low ones, and the rates of oxidation are in the order given, carotin being most readily oxidized.

A rapid method is described of polmerizing formaldehyde to sugar, which has a definite end reaction, and yields calcium and sodium tartrates as bye-products.

INDEX.

The names of new genera and species are printed in italics.

END OF VOLUME XXX.

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